AN ASSESSMENT OF CENTRALIZED INTERMEDIATE MAINTENANCE UPON COMBAT CAPABILITY

THESIS

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THESIS

Presented to the Faculty of the School of Systems and Logistics of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Logistics Management

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Abstract

The purpose of this ~~study~~ thesis was to evaluate the relative performance and cost of centralized intermediate maintenance versus traditional organic maintenance. The study had three objectives: 1) Measure peacetime readiness performance for centralized and organic intermediate maintenance; 2) Measure wartime combat capability performance for both maintenance concepts; AND 3) To compare maintenance costs between centralized and organic intermediate maintenance concepts.

The objectives were accomplished through statistical analysis of the Jet Engine Maintenance Simulator (JEMS) simulation model for F16 F110 engines. The cost comparisons were obtained from Air Force Logistics Command ~~(AFLC)~~ agencies and the F16 Systems Program Office ~~(SPO)~~.

Analysis of the simulation results found that peacetime readiness rates were statistically the same for 26 of 30 peacetime simulations. Of the four results which showed significant differences, three favored organic maintenance while one favored centralized maintenance. Different simulations were made for varying transit times, maintenance crews, and quantity of spares. Keywords: cost analysis,

The wartime results found statistical differences in aircraft availability on 20 of the 30 simulation runs. Of

aircraft availability

these, 16 found higher availability rates for organic maintenance while four found higher rates for centralized structures.

The sustained results found statistical differences in aircraft availability on 28 of the 30 runs. Of these, 25 found higher availability rates for organic maintenance while three found higher rates for centralized structures.

The estimated cost differential for the maintenance structures over the 180 day scenario was $7,458,276. This cost difference included estimates for intermediate support, transportation, initial spares, war reserve spares kits (WRSK), spare F110 engines, replenishment spares, and support equipment.

This study recommended that organic engine support be maintained for F110 engines and that organic intermediate maintenance be preferred for maximum combat capability.

AN ASSESSMENT OF CENTRALIZED INTERMEDIATE MAINTENANCE UPON COMBAT CAPABILITY

I. Introduction

Chapter Overview

This chapter provides a general background on the subject of maintenance planning within the United States Air Force. A review and analysis of the existing maintenance guidelines is provided, along with an examination of the current Air Force maintenance structure. The research problem is stated, and the research goals and objectives are outlined. Also included in this chapter are the scope, limitations, research assumptions, and the definitions of frequently used terms.

Background

The maintenance function within the Department of Defense (DOD) is big business. Within all the services, 900,000 people are involved in maintaining more than $200 billion worth of equipment and weapon systems. All of this maintenance comes at a price tag estimated at above $40 billion per year (31:28-32). The current reality of decreasing DOD funding makes alternative maintenance strategies more attractive. The Air Force's ability to project and sustain combat capability is dependent upon effective maintenance support (32:52). The design,

management, and implementation of this logistics support is dependent upon an overall "systems" approach (35:112-113).

Maintenance Planning

The design and implementation of a maintenance strategy begins early in the acquisition process. This logistics planning process is defined within Air Force Regulation (AFR) 800-8 and is known as the Integrated Logistics Support (ILS) Program. This regulation establishes the Air Force's program for logistics support as required by DOD Directive 5000.39. The purpose of the ILS program is to combine all the technical and management activities associated with the acquisition of an Air Force weapon system. The program is designed to accomplish the following objectives:

1) To include support considerations into the design objectives of the weapon system.

2) To include and relate support considerations into the readiness objectives, system design, and sustainability goals.

3) To acquire the required support for the weapon system.

4) To provide the required support for the operational phase consistent with the identified life cycle cost objectives (35:172-173).

The importance of maintenance planning and its subsequent implementation is crucial to all weapon systems. Maintenance planning is a primary ILS element and is defined as the process conducted to identify and establish maintenance concepts, plans, and requirements for the "on"-aircraft and "off"-aircraft maintenance to be performed during the life of

the weapon system (6:2-3). The designed performance of a weapon system and its operational readiness are embodied in the operational concept. This fact, dictates the consideration of the following:

1) The maintenance concept must be compatible with the operational concept.

2) Hardware design directly influences the design and demand requirements for maintenance.

3) Preventive and corrective maintenance is generated by operations.

4) Supply requirements and the associated support concept are generated as a result of the maintenance effort.

5) Packaging, handling, and transportation needs result from the maintenance actions. (8:5-7)

This maintenance planning effort defines the actions and support requirements necessary to maintain the designed system in its prescribed state of readiness. It considers the various maintenance functions and the levels at which such maintenance should be performed.

Approximately one third of all Air Force resources - people, money, and material - are required each year to satisfy maintenance requirements. Failure to properly plan the expenditure of these resources can greatly reduce Air Force effectiveness, and consequently lower Air Force combat capability (24:2-3).

Maintenance Concept

The maintenance concept is included in the initial weapon system documentation phases of the acquisition process. The maintenance concept is a general plan that sets the broad

parameters in which a support system must be designed. The concept establishes maintenance requirements, supply considerations, and constraints for a proposed new system (24:7-8).

This initial maintenance concept helps formulate the design characteristics needed to obtain the optimum balance between operational effectiveness and life cycle costs. In the long run of the life cycle, maintenance costs are typically the greatest cost factor influencing support costs.

After the initial maintenance concept has been established, the systems engineering and logistics plans are formulated. The maintenance concept is developed first to serve as a guide for logisticians and designers in planning their efforts, in context with both operational and maintenance requirements.

When the weapon system and the corresponding logistics support have been designed adequately, the maintenance concept becomes the maintenance plan and is then published as part of the Integrated Logistics Support Plan (ILSP). This maintenance plan is a formal document which provides detail to the maintenance concept and describes the technical requirements and design parameters. Its objective is to prescribe a plan of action for each significant item of a system throughout its life cycle (11:112,138).

Maintenance Planning Guide

During the earliest phases of the acquisition cycle, the maintenance concept guides the design of the logistics support system. Included are factors such as the maintenance environment (basing concept, climate, organization) and support factors (fully mission capable rates, sortie generation rates, etc.). During the demonstration and validation phase of acquisition, trade-off studies are made to refine the maintenance concept. These studies influence and impact the repair level decisions for different maintenance concepts.

Included in these tests are factors such as repair location, data collection sources, technical requirements, and program management objectives. Once these studies are complete, the more detailed maintenance plan is published to allow the acquisition cycle to enter the Full-Scale Development phase. By this point in time, all "anticipated" major maintenance tasks have been identified and resources set aside to meet these maintenance demands.

During the production and deployment phases of acquisition, the maintenance plan is again reviewed to determine how well objectives have been met. The maintenance plan does not become static, but is allowed to change when deemed necessary. The maintenance plan serves as a reference document during the provisioning process which determines

spare part levels. This process identifies the source and location of repair assets for the weapon system (24:4-6).

The operational and maintenance concepts must be developed concurrently. A proposed operational concept is meaningless if it exceeds projected maintenance capability. Air Force regulation 800-11 also dictates that support requirements be achieved at an affordable cost. The importance of combining both the operational and support plans is obvious. The ability to sustain operational capability is dependent upon maintenance support. The Air Force's future effectiveness during an era of reduced funding, depends upon effective maintenance planning (10:3).

Current Maintenance Concepts

Current Air Force aircraft systems typically use three levels of repair capability. The level of repair decision and its location is important because it impacts the allocation of workloads at both the bases and the depots. These three repair levels are organizational, intermediate, and depot. The relative difficulty of the maintenance tasks increases from organizational level thru depot level. Normally "flight line" and "minor" repair actions are classified as organizational maintenance. Intermediate level maintenance usually involves "off-aircraft" component repair actions. Intermediate level usually requires specialized equipment and more personnel proficiency than organizational maintenance. The final repair level is depot maintenance.

This level requires specific "industrial" capabilities which are not readily available at each operating base. Major modifications and overhauls require extensive engineering expertise which is normally available only at the depot level. The maintenance concept specifies at what level a particular item will be repaired. This repair decision will either generate a new repair requirement or take advantage of an existing repair capability (35:275-276).

Current combat strategies stress the importance of unit "self-sufficiency". Based upon this operations strategy, most units today have organic organizational and intermediate repair capability. Senior Air Force leaders stress the importance of units deploying and operating independent maintenance units. Mobility plans, for deployment overseas, require the airlift of those maintenance assets needed for both organizational and intermediate level maintenance (25:4-7).

The Pacific Air Force (PACAF) maintained an alternative maintenance structure from 1977 thru 1986 for its seven aircraft units. PACAF centralized its intermediate level maintenance at Kadena Air Force Base (AFB) in Okinawa, Japan to minimize airlift requirements and reduce vulnerability for its Korean bases. The attached map and PACAF aircraft assignments are shown in Appendix A and Appendix B. Recent changes in threat assessments for PACAF's centralized repair facility have changed its maintenance strategy, and PACAF is

currently adopting the Air Force's traditional "self-sufficient" structure (15:8-10).

Background Summary

The maintenance structure and strategy for any Air Force weapon system is identified early in the acquisition cycle. Effective maintenance support depends upon the integration of many distinct functions. Among these areas are operational plans, weapon design, maintenance support, and basing strategy. Both the mission and support planners need to be aware of their interdependence. Early resolution of potential conflicts enhances the capability of any weapon syste

Policy planners today rely primarily upon a 3-level maintenance concept. The desire for organic base "self-sufficiency", dictates the location of organizational and intermediate repair capability at the unit level.

Position

This paper takes the position that emerging trends dictate a re-evaluation of the Air Force's current maintenance strategy. Reduced budget funding, improved reliability, and airlift capacity constraints will impact future weapon systems.

The ability of the Air Force to assess alternative maintenance strategies will become a necessity. This paper will examine the maintenance strategy for centralized

intermediate repair. Its focus will be whether centralization of repair assets improves or detracts from the Air Force's ability to sustain combat capability.

Statement of Problem

Peacetime budget constraints and wartime combat capability goals are inevitably at odds. This research will evaluate the efficiency and effectiveness of centralizing intermediate repair within a regional theater. Also, what benefits are gained by centralizing repair assets within a regional theater?

Research Objectives

The overall objective of this study is to identify the impact of centralization of repair assets upon combat capability. To accomplish this, an actual historical example was examined and compared with more traditionally structured units. A means of evaluating maintenance efficiency and effectiveness was needed. Three strategies were pursued to meet the objectives:

1) Reliable maintenance data was obtained from Air Force agencies to measure PACAF's maintenance performance history.

2) Cost data was collected to determine the relative costs within PACAF for the centralized and dispersed maintenance strategies.

3) An F16 engine support simulation model was run to compare peace and wartime combat capabilities for each intermediate maintenance structure.

Investigative Questions

Tc accomplish the research objectives, available literature on the centralized maintenance concept was reviewed, and the Air Force Logistics Command's (AFLC) Comprehensive Engine Management System (CEMS) data was used. The CEMS data from D042 provided current information about F16 engine maintenance from PACAF units and United States Air Forces in Europe (USAFE) units. These available sources and a Jet Engine Management Simulator (JEMS) model addressed the following questions:

1) How does centralized intermediate engine repair impact peacetime capability?

2) Which intermediate repair concept achieves higher wartime combat capability?

3) Does centralization of intermediate repair improve efficiency and reduce overall maintenance costs.

Scope of Study

The only long-term attempt at centralizing intermediate repair assets has been within PACAF. The applicability of this study must be viewed within that context. A conscious effort has been made to choose measurement parameters that might lessen this limitation. Still the fact remains that our results may be solely applicable to PACAF units. The comparison with non-PACAF units represents an effort to explore potential information that might warrant further examination. The multitude of variables impacting upon such

broad measurements as maintenance effectiveness among large Air Force units is difficult to isolate. Each reader must be constantly aware of this research limitation.

Limitations

The availability of data and time constraints limit the research design. The many relevant variables in measuring maintenance efficiency and effectiveness are almost limitless. The high cost nature of propulsion engines made its selection logical because of its critical importance to readiness and the availability of maintenance data. The current shift back to a dispersed maintenance concept within PACAF also limited available data.

The political nature of the topic was also evident. Air Force commanders are hesitant about advocating the "loss of their empires" for improved productivity or efficiency. Most wings currently have direct control over most organizational and intermediate level repair assets. Centralization would dictate the loss of this control and of independent repair capability. Another research limitation is security classifications for relevant studies. The Air Force conducted several studies to assess centralization for USAFE units during 1980-1983. The security classifications for these studies would have required burdensome administrative actions and limited the distribution of this study. The author chose to avoid these limitations and therefore was unable to explore the results of these studies. In addition,

security classifications limited the evaluation of classified vulnerability assessments. Air Force Regulation (AFR) 66-14 authorizes the centralization of repair assets to a "safe haven". The evaluation and consideration of this aspect will not be directly addressed within this study.

Research Assumptions

This study will assume that maintenance performed upon F16 jet engines is representative of overall maintenance performance. The availability and accuracy of the CEMS data made this assumption necessary. The high cost nature of jet engines and their impact upon mission capability generates management interest. Other items probably do not warrant the same amount of visibility or attention.

This study also will assume that the maintenance structure materially impacts mission capability. Factors such as different supply policies, manpower levels, and skill proficiencies will not be specifically addressed. The peacetime comparisons between different wings will focus strictly upon performance results. The many different factors which generate these performance results will not all be examined. The facts which logically relate to the maintenance structure will be focused upon.

Another assumption made will be that the cost of converting to a dispersed maintenance concept is a realized savings of centralization. The PACAF cost figures focus upon the cost of conversion to a dispersed concept.

The final assumption made is that wings with organic intermediate maintenance will deploy as units. The only engine support available will be that which is available at the wing. In essence, no other wing will be able to offer lateral support within a theater.

Definitions

To aid the reader in understanding this study, the following definitions are offered:

1. Maintenance: The act or process of keeping material in a serviceable condition or restoring it to that condition when it fails or malfunctions.

2. Maintenance Concept: The overall repair and logistics support designed to meet operational requirements.

3. Integrated Logistics Support: The process of identifying and assessing logistics support alternatives; integrates support elements to implement combat support doctrine.

4. Organizational (Organic) Maintenance: A level of maintenance which primarily isolates defective components and provides direct servicing to aircraft.

5. Intermediate (Field) Maintenance: A level of maintenance which normally requires specialized equipment or requires component repair capability.

6. Depot Maintenance : A level of maintenance performed by AFLC contract depots. Most major modifications and repairs are conducted at this level.

7. Centralized Intermediate Repair Facility (CIRF): Single intermediate repair facility which serves several bases or weapon systems within a defined region.

8. Pacific Logistics Support Center: Centralized Intermediate Repair facility located at Kadena Air Base, Okinawa which serves all PACAF flying units.

9. Comprehensive Engine Management Systems (CEMS): A management system which collects and monitors jet engine repair status for AFLC.

10. Jet Engine Management Simulator (JEMS): Readiness assessment, Monte Carlo, simulation model developed by AFLC/XRSM.

Summary

This initial chapter has presented the background of maintenance planning and its impact upon repair capability. In addition, the purpose of this study along with its limitations, assumptions, and definitions were presented. The following chapter provides a review of the unclassified research literature.

II. Literature Review

Chapter Overview

This chapter reviews the unclassified literature concerning Centralized Intermediate Maintenance. The chapter begins with the historical origins of the alternative maintenance concept and then traces its development within PACAF. Research studies conducted by the Rand Corporation assess the viability of the concept and later measure its success within PACAF. Finally, a study conducted in early 1987 by PACAF provides current outlooks on the maintenance strategy.

Background

The theoretical origins of the Centralized Intermediate Logistics Concept (CILC) date back into the late 1960's. During the Vietnam conflict the concept was briefly tested for F-4 aircraft. The brief studies showed the concept had some negative aspects and would require extensive improvements in command and control structures (28:2-4). Logistics studies during the mid 1970's re-examined the CILC concept and proposed further testing to evaluate its potential merits.

Historical Origins

The theoretical development of the CILC concept accelerated during the mid 1970's during the Air Force's Maintenance Posture Improvement Program. This research study was tasked with evaluating alternative maintenance structures. The CILC is an alternative logistics support structure which has two main elements. The first is a Centralized Intermediate Repair Facility (CIRF) which repairs avionics, engines, and performs limited field maintenance. The other element in the CILC concept is the Forward Operating Locations (FOLs) which perform flight-line-only maintenance. Some small amount of intermediate or "bench" repair remains at the FOLs but the bulk of "off equipment" (intermediate) maintenance is performed at the CIRF.

An additional element of the CILC is referred to as an Inventory Control Point. This aspect of CILC provides asset visibility and enhances a theater commander's ability to make responsive resource allocation decisions (3:2).

Classified Studies

The Air Force conducted several studies during the 1980-1983 time frame which focused upon comparing centralized intermediate maintenance versus on-base intermediate level maintenance. The classified summary report of these studies was published in 1983 and remains classified. In an effort

to avoid administrative delays and allow unlimited distribution of this study, the author chose to use only unclassified sources. Any "real world" analysis, conducted for actual employment decisions would need to refer to these classified sources.

CILC Development

The Maintenance Posture Improvement Program examined several alternative maintenance concepts and operating structures. The program sought to identify strategies which achieved improved mission capabilities while simultaneously reducing costs. At that time, logistics planners were becoming concerned over the growing cost of maintenance support. In addition to the acceleration in maintenance costs, the planners were concerned about the manner in which costs were increasing. Approximately 66% of the maintenance costs were being incurred at the field or unit level (28:2). If a strategy or concept could be designed which met mission needs and reduced unit's repair costs, its impact would be substantial. This focus upon cost-reduction provided CILC its initial impetus (33:11-12).

As the Maintenance Posture Improvement Program progressed, additional areas of interest began to develop. As the study group examined CILC as an overall strategy, its focus was shifting from cost reduction towards force effectiveness. Among the effectiveness improvements noted were improved mobility, increased sortie production,

improved survivability, and enhanced resource management. The studies suggested that centralized support achieved higher mission capabilities at reduced costs. Centralization improved technical proficiencies, concentrated production management, combined spares, and contributed to improved reliability. These improvements would theoretically improve efficiency, reduce manpower, spares, and support equipment needs. The Inventory Control Point (ICP) would improve supply distribution and responsiveness.

Critical to the CILC strategy was locating the CIRF at a secure "safe haven". The CIRF would be located away from hostile environments to reduce vulnerability and provide added protection to scarce repair assets (3:10-15).

Maintenance Functions

To provide the needed detail, the maintenance functions were divided into avionics systems, engines, aerospace ground equipment, and actual aircraft ("on equipment") items. Unique aspects of these different maintenance activities required this approach. Each maintenance activity was examined for potential cost savings, mission capabilities, and reduced vulnerability. The cost savings were not to be gained from reduced capabilities but from improved efficiency (16:1-3).

Economic Assessments

The principal theoretical cost savings achieved through centralized intermediate repair involved manpower, support equipment, and facilities. Additional costs would be gained in spares and transportation. From the mid 70's studies, it is important to note that F-4's were the primary tactical fighters. The results of the Rand studies focused upon F-4 units. Exercises conducted in PACAF and USAFE estimated the cost impact in implementing a centralized structure. Analysts interviewed shop chiefs and used queueing models to validate the manpower results. The following table summarizes the cost impacts of centralization.

SUMMARY FOR PEACETIME CILC

	USAFE	TAC	PACAF	TOTAL
MANPOWER SAVED	556	771	35	1362
PERSONNEL REMOVED FROM COMBAT OLs	1800		120	1920
BENCH SETS				ADEQUATE
SOME BENCH EQUIP IN LONG SUPPLY (ONE TIME)				$15-18
STOCKAGE COST (ONE TIME)				$16
TRANSPORTATION COST (ANNUAL)	$0.6-0.7	0.5-1.6	0.6-1.4	2-3
FACILITIES COST (ONE TIME)	$1-2	0.25	0.12	1.3-2.4

**COSTS IN MILLIONS

This summary chart represented the bottom line results of detailed calculations performed by Rand. The analysts felt the results represented conservative estimates of potential savings. For the above figures it was estimated there would be two CIRFs in USAFE, two within Tactical Air Command (TAC), and one in PACAF. The inventory of F-4's were divided into: 480 in USAFE, 776 in TAC, and 150 in PACAF (3:7).

The term bench sets used in the table represents the minimum amount of support equipment (across all shops) needed to support a squadron. All the available bench sets would not be needed for peacetime operations under a centralized concept. The table shows the cost of the excessive bench sets equal to between $15 and $18 million.

The additional spares required for the increased repair cycle were estimated at $16 million. The additional time required to transport assets to and from the CIRF creates the need for increased spares. The transportation and facility cost estimates were provided by the commands. Transportation costs were estimated per year and the facility costs are conversion costs. For example, it cost PACAF $120,000 to transform facilities at Kadena AB for its CIRF operations (3:10-12).

Factors Impacting CILC

The multiple factors which impact logistics support create ramifications for centralization. The trade-off of

spares for manpower limits the local commander's flexibility. By removing bench repair from the wing, the commander loses direct control over that repair capability. Ideally, the additional spares should compensate, but people are more flexible than parts. Other pertinent facts are that centralization should allow more remove and replace (RR) actions compared to remove, repair, and replace (RRR) actions. This factor should improve aircraft availability and make the flight line more self-sufficient.

Other factors mentioned within the Rand studies were the savings in airlift requirements, maintaining peacetime structure in combat, and minimizing the time required to transition to war. With CIRFs pre-positioned within potential theaters, the infrastructure and repair capability exists from the very beginning of hostilities (3:10-12).

Maintenance Concept

The Maintenance Posture Improvement group cited increased RR actions at the wings as being positive for aircraft availability. Lengthy repair actions would be avoided, provided that space parts were sufficient. Improved diagnostic systems would allow maintenance personnel to rapidly identify failed components. The CIRFs would be production oriented. The specialized nature of the intermediate tasks required skill proficiencies not readily available at some remote locations. The one year tour cycles often depleted skilled technicians and caused

turbulence. The centralized concept also advocated the gradual growth in CIRF repair actions. Repairs normally accomplished within the United States could be transferred to the CIRFs to reduce turnaround times and improve CIRF productivity (14:9).

PACAF Implementation

The results of the theoretical studies mandated the "real world" testing for CILC. Environmental factors within PACAF targeted it for testing. The two bases located in Korea were perceived to be highly vulnerable and their remote locations created continuous turnover in manpower. The manpower problem was cited by retired Major General Jack Waters as being key to the ultimate implementation of CILC (34). The phased-in field test began in October, 1975. In March of 1977, members of a study team evaluated its effectiveness within PACAF.

PACAF Studies

The principal reason cited in the field studies for CILC was wartime capability. The study concluded that CILC allowed PACAF to transition easily to war, increased sortie rates, improved supply control, and decreased vulnerability. The field studies focused upon four wings of F-4 aircraft and compared pre-CILC performance to the post-CILC performance. Major hypotheses which were evaluated were increased Remove and Replace (RR) actions and fewer Remove,

Repair, and Replace (RRR) actions, improved maintenance quality, and improved supply results. The experimental design compared maintenance performance results for the six months preceding CIRF's implementation to the six months following its installation (5:7-10).

Performance Results

The Rand Corporation conducted the first studies where actual "real world" performance was evaluated under a centralized concept. Among the findings were an increase in remove and replace (RR) actions. Obviously the transfer of intermediate maintenance to th ... RF mandated this increase. The amount of increase in RR actions varied by the bases according to the stocking positions. The Korean bases at Kunsan AB and Osan AB reduced RRR actions by 48 and 51 ercent. Kadena AB in Japan and Clark AB in the Philippines d reductions of 24 and 28 percent (5:15-16). Clark and Kadena had smaller quantities of replacement components on han.. The RRR rates remained below the pre-CILC levels throughout the examination periods. The study mentioned the dichotomy of feelings from maintenance managers about RR versus RRR maintenance. Most managers felt more secure with local intermediate repair being immediately available.

In essence, the flexibility offered by manpower is greatly preferred over additional spare parts (20:9-11). The Rand study suggested that RR actions would enable PACAF to achieve higher aircraft availability rates. In fact the

availability rates increased by 6 and 23 percent at Kunsan AB and Osan AB. At Kadena, the availability rates declined for all airframes. During this time frame, Kadena was increasing its F-4D fleet while decreasing its number of F-4Cs. This change in Kadena's airframes complicates a comparative analysis (5:11).

Manpower Savings

The analysis of PACAF manpower records revealed that only 27 positions were saved as a result of implementing CILC. The study attributes the small reductions to the fact that F-4 engine maintenance had previously been consolidated at Kunsan for both Korean wings. The primary manpower impact was that the annual number of remote tours required in Korea was reduced by 130 men. The relocation of these 130 maintenance slots to Kadena would allow stabilized three year tours and reduce manpower turnover (5:17).

Improved Reliability

In addition to improved readiness rates in Korea and decreased short tours, the maintenance data suggested that the time between maintenance actions was increasing. The Rand study suggested that assembly line production methods were enhancing the quality of maintenance being performed. The increased time between maintenance actions for CIRF items resulted in a 42% reduction in man-hours by the FOLs per sortie (5:19). In essence, the CIRF allowed the wings'

maintenance personnel to devote more time and attention to on-equipment actions. This focus on flight-line maintenance improved sortie production.

Given the positive results of these early studies, PACAF elected to maintain the CILC structure. The primary reasons for its adoption were the perceived threat to the Korean bases, reduction in remote tours to Korea, and the positive impact on peace and war operating capabilities. PACAF felt cost was a secondary factor. In fact, many of the officers interviewed, suggested that the CIRF was established based upon its wartime merits. Mr. Barrett, from headquarters PACAF, who has served on the logistics staff during the entire period, stated that the "CIRF was an integrated logistics concept designed to meet both peacetime and wartime demands" (2). The maintenance structure remained in place until late 1986. At that time, changes in the perceived vulnerability to Kadena made PACAF re-evaluate its maintenance structure. Based upon new basing locations for Soviet Bear bombers, PACAF decided that centralizing all its intermediate repair assets in one location was too risky. The decision was made to disperse intermediate repair back to the individual bases.

One may ask about the remaining vulnerability to the Korean bases. In essence, it narrows down to having several targets instead of one centralized facility. This study remains unclassified, so the exact vulnerability studies were not reviewed. Survivability remains a key measure of

wartime effectiveness and its consideration impacts all logistics strategies. This research acknowledges this shortcoming, and attempts to make general observations concerning vulnerabilities. The existence of secure lines of communication, transportation, and command and control is vital to centralized intermediate maintenance.

Current PACAF Outlook

In early 1987, then Brigadier General Joseph Spiers tasked PACAF agencies to re-evaluate the CILC strategy which was by then referred to as the Pacific Logistics Support Center. The original CIRF at Kadena had been augmented through the years and now included a small depot repair center known as the Support Center for the Pacific (SCP). Consequently the CIRF is known today as the Pacific Logistic Support Center (PLSC).

The assigned study addressed the positive and negative aspects of centralized intermediate maintenance versus dispersed intermediate maintenance.

Positive Impacts (1987)

Among the pros for centralized intermediate maintenance were the following:

1) Centralized management of spares and push distribution allows parts to be pushed to the unit with the greatest need.

2) Co-location with AFLC's Support Center produces synergy and reduces the number of items returned to the U.S. for repair.

3) PLSC serves as a strong, centralized point of contact for AFTO 135 submissions which allows intermediate maintenance to be enhanced.

4) PLSC provides intermediate support for deploying units. Units don't have to rely on airlift for intermediate support.

5) PLSC allows operations to be the same in war or peace. Units don't have to operate without intermediate support for the normal 30 days.

6) Flexible pipeline can support any deployed location allowing easier relocation of units.

7) Personnel benefit from long stable tours at Kadena allowing better training and job continuity versus short tours in Korea.

8) Industrial economies of scale allow cross-cannibalization between support equipment and provide back-up options. For example a Rand study indicates two F-15 AIS's (Avionics Intermediate Sets) operating together can support 50 sorties per day. Independently they support only 28 sorties. (27:10-11)

These current pros for centralized intermediate maintenance parallel many of those mentioned earlier. The experience of PACAF has been that centralization provides both pro and con results. Their overriding concern about survivability dictated their decision to decentralize. Given the existence of a secure "safe haven", PACAF apparently would have been content with centralized maintenance. The cost differential between the concepts is becoming more pronounced. Rising costs in manpower, spares, and support equipment limit funding and the ability of the Air Force to sustain combat capability. PACAF also examined the negative aspects of centralization.

Negative Aspects

Listed among the negatives in the 1987 study were the following:

1) Added pipeline eats up parts with transportation and processing time.

2) The PLSC is less responsive due to pipeline times and less visible and sensitive to unique unit requirements. Unit maintenance commanders would be more likely to use overtime and surge intermediate maintenance production.

3) PLSC requires increased management attention. Units must deal with an added external agency to resolve support problems.

4) Unique nature of PLSC within the Air Force complicates mobility planning for TAC units. TAC units must design unique mobility packages for PACAF deployments.

5) Line replaceable units (LRUs) must be shipped from units to PLSC for Time Compliance Technical Orders (TCTOs). This increases implementation times and creates management problems.

6) PLSC depends upon secure reliable transportation to perform its mission. If that transportation system is hindered or limited during war, the PLSC's effectiveness falls. (27:11)

These negative results of centralization mitigate the positive results. The complexity of the issue touches upon many areas. Logistics support, by its nature includes many different variables which all impact upon a unit's capability. PACAF initially studied and later implemented a centralized structure for intermediate repair. The performance results generally were positive, but to some extent were inconclusive. This study attempts to assess the

mission capability versus the cost of the two structures. This balancing of capability against cost is difficult to accomplish. Current and future fiscal realities dictate that the Air Force tackle this balancing act.

Summary

This chapter reviewed the historical orgins of Centralized Intermediate Maintenance and presented past and present results of the logistics strategy. Current PACAF outlooks on its experience with the maintenance concept were shared along with PACAF's rationale for abandoning the concept. The following chapter describes the research methodology.

III. Methodology

Chapter Overview

This chapter describes the research methodology undertaken to accomplish the research objectives. First, a review of the research questions raised in Chapter I are presented. Then the rationale and incentive for utilizing computer simulation is given. Further, a description and explanation of the Jet Engine Maintenance Simulator (JEMS) model is provided. Finally, the data collection method for maintenance costs is presented and the method of comparing costs is detailed.

Research Objectives

The primary objective of this study is to measure the impact of maintenance structure upon combat capability. The focus is specifically upon intermediate level maintenance. What additional capability does organic, co-located intermediate level maintenance provide a unit? How much does this additional capability cost compared to a centralized intermediate structure? The multiple factors which impact maintenance support performance present many problems in designing a research design. The direct impact of factors such as supply policies, personnel proficiency, and mission assignments all impact maintenance performance.

To gain maximum control over the research environment, the use of computer simulation was selected. Banks and Carson state that simulation is an appropriate methodology to use when experimenting with alternative structures (1:4). The main advantage of simulation models is their ability to capture the interaction effects of elements of a system and display it as a measure of performance. Therefore, if two alternative maintenance structures are available, simulation may be used to test their performance under varying conditions such as repair times, resources available, and transportation times. The simulation model can account for these varying conditions and record performance in the form of a performance measure. If the characteristics of the system are accurately captured by the model, the performance factors generated should be accurate estimators of system performance.

To enhance the credibility of the simulation effort, the author chose an existing AFLC model which had been previously validated. To further enhance the chances of successful replication, "real world" quantities of maintenance resources, spare engines, and flying hours were collected to initialize the model with present F16 engine factors. The engine data on General Electric (GE) F110 engines was readily available and detailed to the degree required by the JEMS model.

The implicit assumption made is that F16 Jet Engine Intermediate Maintenance (JEIM) is representative of

intermediate level maintenance. The JEMS model is specifically designed to allow Air Force managers the ability to assess alternative maintenance concepts.

Jet Engine Maintenance Simulator

JEMS is a Monte Carlo simulation model that is used by aircraft engine managers and analysts to relate engine logistics support to aircraft availability and other measures of mission accomplishment. The model tracks the removal, transportation, resupply, and repair actions required to provide logistics support for propulsion engines. The user can design a specific flying hour scenario and build a variety of alternative support structures. The Monte Carlo nature of the model results in some variability in results due to stochastic events triggered by the use of random number streams. This variability requires the averaging of results from several simulation runs. From the previous experience of the Management Sciences Division at AFLC, the author chose to run JEMS and average the results of five runs. For this study, a comparison will be made between centralized intermediate repair ("Queen Bee Structure") and collocated organic intermediate repair. The output of the model provides the number of available aircraft (based solely upon an installed serviceable engine) and gives utilization statistics about the various maintenance resources. JEMS also outputs a table for specified days to show where the

engines are in the pipeline and where maintenance backlogs are occurring (21:1-3).

Critical to this study is the ability of JEMS to place JEIM at either a Main Operating Base (MOB) or a Forward Operating Location (FOL). This flexibility allowed the author to directly compare a centralized JEIM maintenance concept to an organic JEIM concept. The principle measure of effectiveness will be aircraft availability. Later, the secondary considerations of cost and efficiency will be compared between the two maintenance concepts.

Research Design

The experience of PACAF in utilizing centralized JEIM provided an opportunity to explore its impact and its potential use in other locations. The author chose to compare the potential mission capabilities of two F16 PACAF wings with two F16 USAFE wings. Originally, the author hoped to use JEMS for modeling the GE F110 engine and a modular version of JEMS to compare Pratt and Whitney (PW) F100 engines. Time constraints and the need for a more in-depth analysis of the simulation results prevented the F100 simulations. Currently, the F16 wings chosen for consideration have transitioned to the GE F110 engine. The use of the F110 engines at these locations and the availability of the Comprehensive Engine Management System (CEMS) data made the research choice logical and realistic. The F16 wings chosen were Misawa Air Base (AB), Japan and

Kunsan AB, Korea in PACAF. In the European theater (USAFE), the chosen wings were Ramstein AB, Germany and Torrejon AB, Spain. During the early stages of this research, Kunsan and Torrejon were in the process of conversion to GE F110 engines from PW F100 engines. Consequently, the initial quantity of spare F110 engines was unusually high and the author chose to assume that both wings were fully operational with F110 engines. The quantity of spare F110 engines was adjusted to reflect the "planned" spares levels after completing the transition to F110 engines.

The complex reality was that Kunsan AB and Torrejon AB had a mixture of F100 and F110 engines installed in its aircraft. To utilize JEMS, only one type engine could be present. Therefore, the assumption was made that all wings only had F110 engines installed. By August of 1988, all the wings had completed conversion to F110 engines and only a small remnant of F100 engines remained.

Input Data

Available sources at AFLC provided the required input data for JEMS. Among the other sources were the F16 Systems Program Office (SPO), F110 SPO, and PACAF headquarters. The nature of the study dictated the adoption of a case study approach. Since PACAF alone had operated under a centralized intermediate structure, PACAF was the primary source for data. During the early stages of research, the author met several people who had served in PACAF during the

operation of the CIRF. The use of unstructured interviews with many of these individuals, broadened the author's background. Among those interviewed were Major General Joseph Spiers who served as the Logistics Chief when the decision to decentralize intermediate maintenance was made. Also interviewed were retired Major General Jack Waters who helped establish the CIRF, and retired Colonel Wayne Rosholt who served as the CIRF's commander. The positions held by these individuals made them well qualified to comment on the past and present performance of the CIRF. In addition to these, there were five maintenance officers who served in PACAF who were questioned about the operation of the CIRF. The specific focus of these interviews was upon our research questions. How did the centralization of intermediate repair impact PACAF? Did the Air Force save money? Was peacetime combat capability impacted? Appendix C lists the questions asked during these unstructured interviews. These interviews and perceptions about centralized intermediate maintenance were used mainly as a guide to orient the simulation effort. Areas such as transportation times, aircraft availability rates, supply policies, and repair cycle times were highlighted for further examination through the insights and experiences of those interviewed.

JEMS Data

The JEMS model required a variety of detailed input data about the chosen F16 wings. Among the needed data were peacetime flying hours, spare engine levels, removal intervals for F110 engines, repair pipeline times, and maintenance assets. The author used the available historical data from PACAF to design a hypothetical structure in USAFE with centralized JEIM located at Kemble AB in Great Britain. After the simulation runs were complete for a centralized structure, an organic JEIM structure was modeled. A direct comparison will be made between the centralized structure's performance and the organic structure. What difference, if any, is there between aircraft availability between centralized engine support and collocated organic JEIM support?

The JEMS model was run for 180 periods for the following scenario: 1) 90 days of peacetime operations, 2) 30 days of wartime operations, and 3) 60 days of sustained operations. The peacetime flying hour scenario was initially modelled using "actual" peacetime flying rates. The actual monthly flying hours for the four wings were collected for the previous eighteen months. The actual wartime flying scenarios were classified, so the author chose to set wartime flying rates at 2x the peacetime rate. The sustained flying program was placed at 150% of the peacetime flying schedule.

After several initial simulation runs, it became apparent that the given flying scenario generated little maintenance activity over the 180 day scenario. Most likely, the removal interval of 229 hours was the principle cause. Most F16 aircraft fly approximately 45 hours per month. As a result of this utilization, an aircraft would only receive a new engine every five months. Since the 229 hour interval represents official Air Force projections, it was retained in JEMS and a 312.5 hour interval was used for the wartime and surge scenario. The 312.5 hour interval represented the latest actual data from March, 1988. Recent problems with cracked compression blades will drastically affect removal rates (19).

In an effort to create more maintenance activity, the author increased the flying hour program. The author visited with Mr. Robert Sims of Synergy, Incorporated who is employed as a defense analyst. Mr. Sims is currently conducting a contract study for the Air Force known as the "Plateaus Study" which examines at what levels of reliability should maintenance structures change. The Synergy study is examining the F16A model with PW F100 engines. The scenario includes two PACAF F16 wings and two USAFE F16 wings. The Synergy flying hour program was input into JEMS to compare its results with the previous runs.

In contrast to the actual peacetime data, the Synergy scenario greatly exceeded both PACAF and USAFE wartime capabilities. To mitigate these discrepancies, the flying

hour program was placed at an equally distant point between actual peacetime flying rates and the Synergy study. An important point to be made is that both the centralized JEIM simulation runs and the organic JEIM runs will be impacted the same. In other words, both maintenance concepts are being evaluated under identical flying scenarios (30).

This equal treatment or balancing of research design was maintained throughout the study. Only those variables that change directly with maintenance structure were allowed to vary during the simulation runs. Among those variables were transportation times, spare engine levels, and maintenance resources. A brief discussion of these variables follows with explanations given as to why they vary directly with maintenance concepts.

Transportation Times

One of the primary differences between organic JEIM and JEIM at a centralized facility is the transportation of assets between the repair facility and the flying wings. In this study, Standard Air Force Manual (AFM) 400-1 pipeline times were used to establish a baseline for both JEIM structures. Since collocated JEIM requires no transportation for intermediate maintenance, the JEMS model was adjusted to reflect this reality. For centralized JEIM, the AFM 400-1 standard is four days transit for intra-theater shipments. The transport time for base to depot shipments is eight days for USAFE and nine days for PACAF

wings. The only time an organic JEIM wing would be dependent upon the transportation of assets would be for spare parts and the complete overhaul of the F110. The Air Force currently plans upon a depot return rate of only seven percent. Only seven percent of engine failures should ultimately rely upon depot repair for the F110 engine (7:2-5).

Spare Engines

The added time to the repair cycle caused by the transportation of assets requires additional spare engines. In PACAF, AFM 400-1 allows six additional spare F110 engines for centralized JEIM. Under organic JEIM each wing is authorized eight spare engines for a total of sixteen. Under centralized JEIM at Kadena, PACAF was authorized 22 F110 engines. Within USAFE, the author used the same ratios for the hypothetical centralized JEIM. With centralized JEIM nine additional spare engines were authorized for a total of 27 engines. More were present in USAFE because Torrejon has three squadrons or 72 aircraft. With organic JEIM, the two USAFE bases had eight spare engines at Ramstein and ten at Torrejon. These spare engine levels were input to the JEMS model according to the given scenario. Real world CEMS data reflected the actual number of spare engines. If shortages were present, they were adjusted upwards to reflect the AFM 400-1 engine requirements. After establishing the baseline results,

further runs were accomplished to measure the impact of different spare engines levels.

Maintenance Resources

A principal argument in support of centralizing intermediate repair is improved efficiency and reduced costs (3:4-5). To reflect this position, the initial JEMS runs placed fewer maintenance crews, test cells, rollstands, and hardstands at the central repair facility. After a few initial runs, it became clear that manpower was the principle bottleneck. To provide balance to the subsequent runs, the maintenance resources were made equal for both structures. The principle difference was the transportation time. Did the additional spares compensate for the transportation time? What are the differences between peace and war? The results of these questions will be presented in the following chapter.

Statistical Testing

To evaluate aircraft availability as a measure of effectiveness (MOE), the Z statistic will be used. The average availability of aircraft ready for peace, war, and sustained operations will be calculated for the various scenarios. The actual average for aircraft availability over the previous two years' has been 83.4% for PACAF and 88.8% for USAFE (41). These readiness rates equate to approximately 94 of 113 aircraft being mission capable in

PACAF and approximately 110 of 124 mission capable in USAFE. The possessed aircraft figures are based upon data from June, 1988. Since the sample sizes are greater than 30, Z-statistics will be calculated for each simulation run and will be compared for a centralized JEIM structure versus an organic JEIM structure.

The assumptions which must be met for using the Z statistic are as follows:

1) The sampling distribution of $(X_1 - X_2)$ is approximately normal for large samples.

2) The mean of the sampling distribution of $(X_1 - X_2)$ is $(U_1 - U_2)$.

3) If the two samples are independent, the standard deviation of the sampling distribution is represented by pooling the sample standard deviations (22:334).

The two tailed test will be conducted to determine if aircraft availability is statistically significant at a 95 % level of confidence. The Ho for the test will be that the average availability does not differ. Ha for the test will be that the availability rates do differ. With this design we can be 95% confident in our research results and minimize the chances for a Type I error (22:335).

Research Design

The JEMS model allowed the author to build a research design which focused specifically upon those variables which change directly with maintenance structure. The maintenance structure, as was noted above, directly impacts transportation, spares, repair times, and manpower. The

Rand studies in Chapter II directly cited CILC as a strategy which replaces manpower with spares. The initial runs of the JEMS model utilized standard pipeline factors for transportation, spares, and repair times. Equal numbers of maintenance crews and repair resources were input into JEMS to balance their potential impact upon aircraft availability results. Centralized JEIM was modeled for our two PACAF wings as well as our two USAFE wings. Following these initial runs, it was decided to measure the impact of transportation time upon aircraft availability. If the repairable assets could be transported in two days rather than four, how would that impact aircraft availability? Simulation runs for centralized JEIM were accomplished for the standard four day in-theater transit times and later for two, five, and six days. The objective was to determine if transportation was a bottleneck in the repair process. These different transportation times will be statistically tested to determine whether they vary significantly from co-located JEIM repair.

After this was accomplished it was decided to make simulation runs by increasing F110 spare engines by 25% for both PACAF and USAFE wings. This increase in spares was accomplished for both centralized JEIM and organic JEIM structures.

Following these early runs it was evident that manpower shortages were creating backlogs in JEIM. To adjust for this problem, the number of maintenance crews was increased

by approximately 33% for both structures. These results also were statistically tested to determine if any difference in availability existed.

The final simulation runs evaluated more realistic pipeline factors. Pipeline studies show that pipeline times are almost always exceeded. Therefore the repair cycle times were increased by 25% to assess its impact upon F16 availability. These results also were tested statistically for comparison. In essence, the JEMS model allowed they author to evaluate the independent impact of transportation, spares, repair crews, and repair times upon aircraft availability rates.

From the review of the literature in Chapter II, these factors greatly impact any maintenance organization's performance.

Maintenance Cost Data

The JEMS model was used primarily as a capability assessment tool. Intuitively, one can recognize that additional time in the repair cycle for transportation degrades combat capability. The JEMS model allowed the author to measure the impact of centralized JEIM versus organic JEIM. In this portion of the study the focus will be upon the comparative costs of the different maintenance support structures. The cost elements which will be compared are intermediate support costs, transportation, initial spares, war reserve spares kits (WRSK), spare

spares, and support equipment. Data was collected from PACAF and other agencies which depicted the difference in costs between organic intermediate maintenance and centralized intermediate maintenance.

Intermediate Support Costs

Based upon the reported costs for F100 intermediate maintenance in the first quarter of 1987, a comparison will be made between PACAF and the USAFE wings. The maintenance support costs for the four wings will be collected and then converted to a maintenance cost per flying hour. The data will then be used to compare the hypothetical costs for several of the JEMS runs. The use of this data will allow the author to match "real world" cost data with the simulation results. Among the assumptions made is that F100 maintenance costs are not greatly different from F110 costs. The modular nature of the F100 engine may call this assumption into question. Still the analysis will be made for both centralized JEIM and organic JEIM.

Transportation Costs

Added to the centralized JEIM maintenance costs will be a charge for transportation. The Military Airlift Command was contacted to obtain shipping charges which would be in effect for F110 engines. The weight and dimensions of F110 engines were used to determine the roundtrip cost to the Tactical Air Command for transporting F110 engines. The

actual number of F110 removals is provided by the JEMS simulation model.

Initial Spares, WRSK, Replenishment Spares

The maintenance "Plateaus Study" being conducted by Synergy includes cost comparisons for centralized maintenance versus organic maintenance. Based upon the life cycle cost data provided by Synergy, the author will make comparisons for the study's 180 day scenario. The relative costs for initial spares, WRSK, and replenishment spares will be calculated for each maintenance concept. Simplistic assumptions about interest rates, cost allocations, and economies of scale will be made to facilitate the comparison.

Spare Engine Costs

The current costs of F110 engines (March, 1988) will be compared between the two maintenance structures. This cost will not include recurring maintenance and will be computed as a spare engine cost per aircraft. The total cost will include the price of warranty which is usually purchased from General Electric.

Support Equipment Costs

The F16 SPO contracted with Technology Applications, Incorporated in Dayton, Ohio to study support equipment costs between PACAF and USAFE. Based upon Technology

Applications' study, the difference in support equipment costs is shown. The study divided support equipment into three different categories. The categories were avionics (AIS), engines, and others. Based upon this data, the author computed a support equipment costs per aircraft. This assumes the support equipment will remain in service for the life of the wing and does not include its maintenance costs. The only costs considered are the current procurement costs.

Overall Cost Comparison

The overall cost comparison was obtained by combining the previously mentioned cost elements: intermediate support, transportation, initial and replenishment spares, WRSK, spare engines, and support equipment. Which maintenance structure costs more? Does centralization really save money? At what cost does organic JEIM achieve higher combat capability? These cost comparisons represent rough estimates and readers should recognize that many other elements would require consideration. Costs for facilities, training, and personnel are among those not considered.

Summary

This chapter briefly restated the study's research objectives and outlined the research design. The methodologies outlined within this chapter will examine the

impact of centralized intermediate repair from three distinct perspectives.

The first perspective is the historical results from PACAF. The use of PACAF documents and research studies allowed the author to build realistic scenarios for computer simulation. The use of the JEMS model provided a combat capability assessment measure of comparison. The final comparison made will be upon the relative costs of the different support structures. This research design offers a realistic assessment of the costs and benefits of different intermediate maintenance concepts.

IV. Results

Chapter Overview

This chapter presents the research results of this study. First, the JEMS simulation results are given and compared statistically. Aircraft availability rates were compared for both intermediate maintenance concepts. Following the availability comparisons, the costs of the alternative maintenance concepts were examined. Both fixed costs and variable costs were collected to measure the relative economy of the two maintenance strategies.

Introduction

The ultimate goal of this research was to evaluate the impact of centralized intermediate maintenance upon mission capability and cost. The principle measure of merit for capability assessment was aircraft availability. The JEMS model allowed the author to have maximum control over the research environment and to directly input current "real world" facts into the simulation model. This research design combined computer simulation with reality. The cost data was collected from AFLC agencies and companies which were conducting cost studies for the Air Force. This combined approach allowed the author to compare both the relative benefits and costs of the alternative maintenance structures.

This chapter is divided into five sections. First, the peacetime scenario is compared for aircraft availability. Sections two and three focus on the wartime and sustained scenarios. These sections summarize the aircraft availability results and present the statistical comparisons between the two concepts. Section four presents the cost comparisons between the two concepts. Fixed costs such as support equipment, initial spares, and war reserve materials are compared along with on-going maintenance support costs. Section five combines the data to provide an overall analysis of the results. It summarizes the positive impact of organic intermediate maintenance on aircraft availability, but also includes an estimate of the additional costs incurred for this capability.

Scenario Description

Before presenting the simulation results, a review of the scenario being evaluated is appropriate. The peacetime flying hour scenario was based upon 45 hours per month for each possessed aircraft. In our study the following possessed aircraft data was used which was current in June, 1988:

BASE	NUMBER OF A/C
Misawa	53
Kunsan	60
PACAF (Total)	113
Ramstein	52
Torrejon	72
USAFE (Total)	124

The JEMS daily flying rate was based upon 23 actual flying days within a month. Major Keith Hicks from HQ AFLC stated that this was the current estimate for flying days within a month (18). Based upon this data the peacetime flying rate was as follows:

BASE	HRS/DAY
Misawa	104
Kunsan	117
PACAF (Total)	221
Ramstein	102
Torrejon	141
USAFE (Total)	243

Standard repair cycle times from AFM 400-1 were used in the scenario. The repair times are depicted in Appendix D. The removal and installation time for a F110 engine was estimated at four hours. This estimate was provided by SMSgt Larry Lambright from the F16 SPO. SMSgt Lambright has had extensive experience with the F16 propulsion engines. The combined mean removal interval (CMRI) for the F110 engines was set at the official Air Force estimate for the third quarter of 1988 for 229 hours. The maintenance resources which existed at the time this study was conducted were input into the JEMS model. The number of maintenance crews was estimated based upon Tactical Air Command's (TAC) authorization of 52 engine technicians for a 72 aircraft wing (12). Spare engine levels were set to the level computed for a centralized structure or an organic structure. A summary of the maintenance resource factors, maintenance crews, and spare engine levels are provided in

Appendix E. The performance of the wings under centralized JEIM versus organic JEIM was provided by the JEMS model. Centralized JEIM results were evaluated for different transportation times from the FOLs to the CIRF. Also, the impact of increasing spares, crews, and repair cycle times was evaluated for both organic and centralized intermediate maintenance.

Section One: Peacetime Availability

The aircraft availability for centralized JEIM was provided by the JEMS model for both PACAF and USAFE bases. Separate runs were made for transit times of two, four, five, and six days between the MOB and the FOL. This was done principally because of a comment by retired Major General Jack Waters who was instrumental in establishing the CIRF. Waters felt that the CIRF in PACAF could have performed better if adequate resources had been put into transportation assets. Transit times between PACAF bases and the repair facility at Kadena averaged approximately six days for F110 engines in our study. PACAF relied predominantly upon MAC space available resources and no dedicated airlift assets were available to support the transport of items between the CIRF and the PACAF bases. To evaluate this concern, several different transport times were input into the JEMS model (34).

Peacetime Results

The following tables provide the average peacetime aircraft availability for peacetime conditions. The tables reflect the results for PACAF, and USAFE under both a centralized maintenance concept and an organic concept.

TABLE 1.
Mean Availability Results for
PACAF Centralized JEIM (Baseline)

TRANSIT TIME (DAYS)	MEAN NUMBER OF A/C AVAILABLE	MEAN PERCENTAGE AVAILABLE
2	95.421	84.4
4	95.233	84.3
5	94.954	84.0
6	95.571	84.6
4 (Repair Cycle 25%)	95.000	84.1

Mean Availability Results for
PACAF Organic JEIM

NO TRANSPORT	MEAN NUMBER OF A/C AVAILABLE	MEAN PERCENTAGE AVAILABLE
Between FOLs-CIRF	95.153	84.2
Repair Cycle (25% increase)	95.724	84.7

TABLE 2.
Mean Availability Results for USAFE
Centralized JEIM

TRANSIT TIME (DAYS)	MEAN NUMBER OF A/C AVAILABLE	MEAN PERCENTAGE AVAILABLE
2	111.454	89.9
4	111.596	90.0
5	111.558	90.0
6	111.638	90.0
4 (RC 25%)	110.650	89.2

** RC - Increased Repair Cycle

Mean Availability for USAFE
Organic JEIM

NO TRANSPORT	MEAN NUMBER OF A/C AVAILABLE	MEAN PERCENTAGE AVAILABLE
Between FOLs-CIRF	111.571	90.0
Repair Cycle (25% increase)	111.641	90.0

These results reflect standard repair times except for the last entry which reflected an increase of 25 percent in the repair cycle. Pipeline studies illustrate that Air Force engines normally exceed pipeline standards (23:5-3-5-5). As a result, these availability rates may be considered optimistic. From reviewing the above results, it appears that reducing transportation time and increasing repair cycles has very little impact. Most likely, the spare engine levels and the maintenance resources are adequate to meet peacetime flying schedules. The peacetime results for increasing the number of spare engines by 25 percent and

crews by 25 percent are depicted in the statistical analysis section. These readiness results closely parallel the actual peacetime standards of 85% in PACAF and 90% in USAFE. It is important to remember that JEMS is only accounting for the presence of an installed serviceable engine. Obviously many other component systems determine real world readiness.

Statistical Analysis

In order to assess the significance of the differences in availability, statistical tests were performed. Since in all cases, the sample sizes equaled at least thirty, an assumption was made that the data was normally distributed. A Z-statistic was calculated for each scenario comparing the number of aircraft available under centralized JEIM to the number available under organic JEIM. The null hypothesis (Ho) was that there was no difference between the population means in terms of the number of aircraft available, and the alternative hypothesis (Ha) was that there was a significant difference. Once this result was obtained, it could be determined if one sample was significantly different, either greater or smaller than the comparative sample. The peacetime comparisons for PACAF and USAFE follow:

TABLE 3.
PACAF Peace (Baseline)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 Days	95.421	1.83	48	95.153	1.65	34	.796
4 Days	95.233	1.83	48	95.153	1.65	34	.206
5 Days	95.954	1.45	48	95.153	1.65	34	-.564
6 Days	95.571	.48	48	95.153	1.65	34	1.433
RC (25%)	95.000	2.79	48	95.724	.724	34	-1.780

**RC - Increased Repair Cycle

TABLE 4.
USAFE Peace (Baseline)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	111.454	1.13	48	111.571	.53	34	-.620
4 DAYS	111.596	.35	48	111.571	.53	34	.239
5 DAYS	111.558	.33	48	111.571	.53	34	-.097
6 DAYS	111.638	.30	48	111.571	.53	34	.666
RC (25%)	110.650	4.100	48	111.641	.38	34	-1.660

** RC - Increased Repair Cycle

These results reveal there is no statistical difference in peacetime availability at the standard confidence level of 95%. The closest the results came to being statistically significant were when the repair cycles were increased by 25 percent. For PACAF, the Ho can be rejected at the 92.5% confidence level. For USAFE the hypothesis can be rejected at the 90.3% confidence level. These results strongly

suggest that there actually is a significant difference in aircraft availability between maintenance concepts when the repair cycle increases.

What happens if the number of spare F110 engines is increased by 25%? In PACAF, the spares computations allowed 22 engines for centralized JEIM at Kadena and 16 engines if the maintenance is performed at the bases. An evaluation of both concepts with 28 engines in PACAF for centralized JEIM and 34 engines in USAFE for centralized JEIM was completed. Also increased were the organic spares from 16 to 22 in PACAF and from 18 to 24 in USAFE. These ratios basically maintained the differential in spares for each maintenance concept. The statistical results for these simulations follow:

TABLE 5.
PACAF Peace (Increased Spares)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	95.42	1.25	48	95.32	1.28	34	.351
4 DAYS	95.42	.95	48	95.32	1.28	34	.380
5 DAYS	95.15	.78	48	95.32	1.28	34	-.693
6 DAYS	95.28	1.46	48	95.32	1.28	34	-.124
RC (25%)	95.32	1.27	48	95.72	.30	34	-2.100

** RC - Increased Repair Cycle

TABLE 6.
USAFE Peace (Increased Spares)

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	111.65	.263	48	111.60	.353	34	-.671
4 DAYS	111.58	.263	48	111.60	.353	34	-.321
5 DAYS	111.65	.264	48	111.60	.353	34	.726
6 DAYS	111.51	.579	48	111.60	.353	34	-.901
RC (25%)	111.28	1.140	48	111.64	.380	34	-1.950

** RC - Increased Repair Cycle

Once again there was very little statistical difference in peacetime availability for organic versus centralized. The only actual difference again fell in PACAF for the increased pipeline scenario. In USAFE, a difference in the increased repair cycle scenario can be rejected at the 94.8% level of confidence. It is important to note that this scenario more accurately reflects "real world" repair cycles. The transit time within PACAF and the actual repair cycles normally exceed repair standards. In essence this scenario more accurately replicates the real world environment, whereas the others are optimistic in nature.

The final peacetime scenario involved increasing manpower levels. Originally ten repair crews were placed at each CIRF. A repair crew consists of four technicians for this study. This number allowed for three additional crews to be located at the FOLs for the removal and installation of engines. For the initial JEMS runs it became apparent that manpower was the principle bottleneck. Virtually all

of the JEIM backlog was attributed to a shortage of crews. To adjust for this problem, the author increased crews from ten to fifteen at PACAF's CIRF and from thirteen to eighteen at USAFE's CIRF. These changes increased crews from 16 to 21 in PACAF and from 18 to 23 in USAFE for centralized JEIM. Organic crew increases matched centralized increases. These increases placed the additional crews wherever the JEIM maintenance was being performed. For centralized JEIM, the additional crews were placed at the CIRFs; whereas for organic JEIM, they were located at the individual bases. The statistical results of differences in availability follows:

TABLE 7.
PACAF Peace (Increased Crews)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	95.70	.241	48	95.506	.424	34	2.410
4 DAYS	95.52	.495	48	95.506	.424	34	.108
5 DAYS	95.24	.620	48	95.506	.424	34	-2.280
6 DAYS	95.33	1.280	48	95.506	.424	34	-.845
RC (25%)	95.29	1.240	48	95.676	.278	34	-2.070

** RC - Increased Repair Cycle

TABLE 8.
USAFE Peace (Increased Crews)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	111.463	1.142	48	111.576	.322	34	-.650
4 DAYS	111.713	.218	48	111.576	.322	34	.788
5 DAYS	111.633	.341	48	111.576	.322	34	.057
6 DAYS	111.463	1.142	48	111.576	.322	34	-.650
RC (25%)	111.575	.307	48	111.606	.357	34	-.410

** RC - Increased Repair Cycle

The statistical results from the increased crew runs provided mixed results. The USAFE results showed no significant difference in the availability rates. The PACAF results showed statistical differences on three occasions. The two day transit runs showed that centralized JEIM provided better availability than organic JEIM. The five day transit run and the increased repair cycle run showed organic JEIM with better availability. These results lead one to believe that under a peacetime scenario, centralized JEIM can match organic JEIM results if repairable assets can be shipped and received within four days.

In assessing the peacetime results, it appears that there is only a small differential in availability for organic JEIM versus centralized JEIM. The more realistic repair cycle simulations suggest a substantial difference,

but the more optimistic transit times show little difference. In essence, if the Air Force can ship items within theater in four days or less, centralized JEIM produces comparable availability rates. Over the entire scenario for peace, the results were averaged and determined that organic JEIM provided .7094 more aircraft per day. This totals to 63.85 aircraft over the entire ninety day scenario and increases availability by only .299%. In essence, there is little or no difference in mission capability between the maintenance concepts for peacetime operations.

Section Two: Wartime Scenario

The wartime scenario made the normal adjustments for wartime conditions. The repair cycle was shortened to reflect the adoption of twelve hour shifts and the flying hours were doubled to reflect the wartime surge requirements. No additional manpower assets were added to place the existing structures to the maximum test. Airlift constraints make this assumption appropriate. The only available JEIM was that at the organic wings or the CIRFs. The depot continued to provide depot support, but no lateral support capability was allowed to exist within the JEMS model. Although most plans call for a four to seven day surge, the author chose to maintain the increased flying scenario throughout the thirty days. This fact provides more wartime results for comparison. The different

transportation times were maintained and it was assumed that the transportation routes would remain in service. This last assumption touches on the vulnerability issue of centralized maintenance. As mentioned earlier, this study attempts to only assess the potential impact of centralization. Vulnerability issues and survivability issues fall outside the limited scope of this study. The study also assumes that the organic JEIM assets remain in service and survive, so the author feels the balance in the study is maintained. The following tables show the baseline availability results produced by the JEMS model. The statistical results are also included to reflect the relative differences in the maintenance results.

TABLE 9.
PACAF Wartime (Baseline)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	78.38	6.77	30	80.59	3.46	30	-1.580
4 DAYS	73.16	6.32	30	80.59	3.46	30	-5.640
5 DAYS	79.74	3.74	30	80.59	3.46	30	-.977
6 DAYS	80.84	6.86	30	80.59	3.46	30	.181
RC (25%)	68.71	6.26	30	91.51	2.41	30	-22.940

** RC - Increased Repair Cycle

TABLE 10.
USAFE Wartime (Baseline)

Centralized JEIM Availability Versus Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	95.61	4.82	30	104.84	2.64	30	-9.190
4 DAYS	103.96	3.33	30	104.84	2.64	30	-1.130
5 DAYS	106.50	2.80	30	104.84	2.64	30	2.350
6 DAYS	108.98	1.97	30	104.64	2.64	30	6.877
RC (25%)	73.63	9.07	30	106.78	2.19	30	-19.440

** RC - Increased Repair Cycle

The wartime results generally reflect that organic JEIM does provide more aircraft. There were some instances in USAFE where centralized JEIM provided higher availability rates. For the USAFE five and six day scenarios, the centralized JEIM results produced higher aircraft availability rates. On the other hand, the large negative Z statistics for increased repair cycles clearly show the additional capability offered by organic JEIM. The JEMS results clearly show that repair capacities are quickly exceeded during the wartime setting and that only additional manning would impact JEIM support. Given the current manning within most TAC wings, it appears that this would become the primary constraint. Whether the structure is centralized or organic may become irrelevant to the JEIM effort. On balance however, organic JEIM eliminates the transportation requirements and shortens the resupply cycle.

This positive impact is particularly relevant in the increased repair cycle simulations.

Following the baseline runs, the increased spares scenario was run for the wartime scenario. The results of the additional spares are shown in the following tables:

TABLE 11.
PACAF Wartime (Additional Spares)

Centralized JEIM Availability Versus Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	84.98	5.56	30	92.48	2.81	30	-6.56
4 DAYS	79.18	5.20	30	92.48	2.81	30	-12.32
5 DAYS	80.41	6.15	30	92.48	2.81	30	-9.78
6 DAYS	74.37	8.68	30	92.48	2.81	30	-10.87
RC (25%)	76.22	6.40	30	93.39	.826	30	-14.38

** RC - Increased Repair Cycle

TABLE 12.
USAFE Wartime (Additional Spares)

Centralized JEIM Availability Versus Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	110.42	.97	30	111.44	.333	30	-5.42
4 DAYS	108.78	6.96	30	111.44	.333	30	-2.63
5 DAYS	109.92	2.04	30	111.44	.333	30	-4.01
6 DAYS	100.04	5.99	30	111.44	.333	30	-10.41
RC (25%)	92.69	6.36	30	106.79	2.19	30	-11.48

** RC - Increased Repair Cycle

The results are very evident for these simulations. In all cases the large negative Z-statistics show that organic

JEIM provides more available aircraft. The fact that the maintenance crews are readily available reduces the repair cycle times. The negative impact of increased transportation requirements is readily apparent.

The final wartime scenario again involved increasing the number of four man maintenance crews. Once again as was done for peace, the crews were increased from fifteen to eighteen for CIRFs and to twenty-one and twenty-three for organic runs. The relative impact is shown in the following tables:

TABLE 13.
PACAF Wartime (Additional Crews)

Centralized JEIM Availability Versus Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	94.44	.71	30	91.51	2.59	30	5.97
4 DAYS	91.25	2.49	30	91.51	2.59	30	-.41
5 DAYS	93.72	1.66	30	91.51	2.59	30	3.93
6 DAYS	76.22	6.40	30	91.51	2.59	30	-12.13
RC (25%)	83.21	3.63	30	92.53	2.82	30	-11.10

** RC - Increased Repair Cycle

TABLE 14.
USAFE Wartime (Additional Crews)

Centralized JEIM Availability Versus Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	111.49	.27	30	111.37	.45	30	1.28
4 DAYS	111.31	.31	30	111.37	.45	30	-.54
5 DAYS	110.99	.46	30	111.37	.45	30	-3.24
6 DAYS	92.69	6.36	30	111.37	.45	30	-16.05
RC (25%)	106.21	3.89	30	106.79	2.19	30	-7.22

** RC - Increased Repair Cycle

The overall results for the wartime scenario for additional crews reflects that organic JEIM does provide additional aircraft. For PACAF however, it appears that transit times of five days or less provide the advantage to centralized JEIM. As the transportation time increases the advantage shifts back to organic JEIM. Apparently at this point, the additional spares provided to a centralized structure become depleted and the relative advantage shifts to organic JEIM. The same trend appears in USAFE only for transit times less than four days. In general, the conclusion can be made that wartime effectiveness is enhanced with collocated organic JEIM provided that centralized repair requires more than four days transportation. At what additional cost does this capability exist? That question will be addressed when the cost comparisons are made. Overall the wartime scenario

showed that organic JEIM provided 18.532 more aircraft per day on average than centralized JEIM. The bulk of these additional aircraft came from the "realistic" repair cycle scenario and the longer transit scenarios. These results show that a total of 555.98 more aircraft would be available for a thirty day war and that it increases availability by 7.8% over the duration of the war.

Section Three: Sustained Scenario

The final capability assessment comparison will be for sustained operations. This scenario continued after the wartime scenario for sixty days from day 120 until day 180. The flying schedule was set at 150% of the peacetime schedule and the repair cycle was adjusted according to AFM 400-1 standards. All other planning factors remained unchanged and no additional manning was added. This fact should provide continuity to the overall scenario. The cumulative results of the preceding peace and wartime scenarios carry through the sustained operations. The baseline results of sustained operations are shown in the following tables:

TABLE 15.
PACAF Sustained (Baseline)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	75.34	4.28	60	85.19	4.35	60	-12.49
4 DAYS	65.26	2.35	60	85.19	4.35	60	-31.18
5 DAYS	75.23	2.03	60	85.19	4.35	60	-16.04
6 DAYS	71.85	2.64	60	85.19	4.35	60	-20.29
RC (25%)	52.42	2.44	60	91.93	2.51	60	-87.33

** RC - Increased Repair Cycle

TABLE 16.
USAFE Sustained (Baseline)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	98.36	5.66	60	107.89	2.44	60	-11.97
4 DAYS	103.89	4.18	60	107.89	2.44	60	-6.40
5 DAYS	107.14	3.30	60	107.89	2.44	60	-1.43
6 DAYS	109.54	2.17	60	107.89	2.44	60	3.90
RC	108.47	3.49	60	111.59	2.77	60	-6.90

** RC - Increased Repair Cycle

All of the statistical results show a significant advantage for organic JEIM except for the five and six day scenarios for USAFE. In fact the six day scenario shows centralized JEIM with more available aircraft. Further examination of the JEMS output products offered no explanation for these occurrences. The large negative Z-scores for PACAF and the overall trend strongly support

organic JEIM. The variability within the JEMS model could be a possible explanation. In general though, organic JEIM offers substantial improvement over centralized JEIM for sustaining engine support over a 180 day scenario.

To match the peace and wartime results, the simulation was repeated with additional spares input into the scenarios. Identical increases were again made to both the organic and centralized structures. In PACAF, centralized JEIM increased from twenty-two to twenty-eight spare engines. In USAFE, centralized JEIM increased from twenty-seven to thirty-four spare engines. Organic increases were from sixteen to twenty-two in PACAF and from eighteen to twenty-four within USAFE. The statistical results of having these increased spares follow:

TABLE 17.
PACAF Sustained (Increased Spares)

Centralized JEIM Availability Versus Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	82.01	3.71	60	94.43	2.19	60	-22.35
4 DAYS	76.1	2.38	60	94.43	2.19	60	-59.54
5 DAYS	74.33	4.14	60	94.43	2.19	60	-33.24
6 DAYS	53.75	2.23	60	94.43	2.19	60	-100.75
RC (24%)	66.64	3.01	60	94.02	1.42	60	-54.70

** RC - Increased Repair Cycle

TABLE 18.
USAFE Sustained (Increased Spares)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	111.06	.88	60	111.59	.277	60	-4.42
4 DAYS	110.61	1.43	60	111.59	.277	60	-5.19
5 DAYS	107.74	3.28	60	111.59	.277	60	-9.05
6 DAYS	92.16	1.40	60	111.59	.277	60	-105.10
RC (25%)	85.60	1.67	60	109.07	3.02	60	-52.68

** RC - Increased Repair Cycle

In each of the above comparisons, organic JEIM provides significant improvement in aircraft availability. The results suggest that over time the transportation time will have a cumulative impact upon readiness. The results suggest that for peace or for short wars, either concept offers adequate engine support. For long-term sustained engagements, organic JEIM offers clear advantages.

Once the baseline results and additional spares runs were complete, the additional crews scenario was repeated for the sustained portion of the simulation. Once again crews increased from ten to fifteen at PACAF CIRF locations and from sixteen to twenty-one in PACAF for organic JEIM. In USAFE, the crews increased from thirteen to eighteen at CIRF locations and from eighteen to twenty-three at organic locations. The results of the increased maintenance crews are reflected in the following tables:

TABLE 19.
PACAF Sustained (Increased Crews)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	95.49	.54	60	93.34	2.64	60	6.18
4 DAYS	94.04	2.36	60	93.34	2.64	60	1.52
5 DAYS	94.54	1.55	60	93.34	2.64	60	3.02
6 DAYS	66.64	3.01	60	93.34	2.64	60	-51.68
RC (25%)	86.77	5.32	60	94.43	2.19	60	-10.31

** RC - Increased Repair Cycle

TABLE 20.
USAFE Sustained (Increased Crews)

Centralized JEIM Availability Versus
Organic JEIM Availability

	CENTRALIZED			ORGANIC			
SCENARIO	MEAN	SD	N	MEAN	SD	N	Z
2 DAYS	111.557	.33	60	111.67	.31	60	-1.96
4 DAYS	111.603	.26	60	111.67	.31	60	-1.31
5 DAYS	111.493	.32	60	111.67	.31	60	-3.10
6 DAYS	85.597	1.68	60	111.67	.31	60	-118.48
RC (25%)	108.470	3.49	60	111.59	.28	60	-6.90

** RC - Increased Repair Cycle

The added maintenance crews produced some diversity. In PACAF, centralized JEIM produced improved results for transporting assets within five days or less. In USAFE, organic JEIM was statistically better in each case except for the four day scenario, where the level of statistical significance reached only 80.9%. In both theaters, transportation times greater than five days gave organic

JEIM the advantage. The realistic pipeline scenarios also produced superior results for organic JEIM. The mixed results show that centralized JEIM can produce competitive results to organic JEIM if the transit times are decreased sufficiently. If demand does not justify the increase in transportation assets or the cost of improvement is too high, then organic JEIM has clear advantage over centralized JEIM.

The overall impact upon readiness for organic JEIM versus centralized JEIM was 22.57 more aircraft per day. This totaled to 1354.68 aircraft over the sixty day scenario. This amounted to an increased availability of 9.5% for both theaters.

Overall Results

The overall conclusion that can be made from the results is that centralized JEIM can offer comparable peacetime and wartime availabilities if sufficient spares and transportation assets are made available. For sustained operations or for longer repair cycles, organic JEIM offers clear advantages. Current engine maintenance practices suggest that there are insufficient dollars available for procuring these assets for a centralized structure. Air Force leaders have adopted a "self sufficiency" attitude for their tactical units and have implemented logistics support systems with this strategy in mind. The next section will deal with the economic impact of centralized intermediate

maintenance versus organic intermediate maintenance. The study until now has focused exclusively upon engine maintenance. The cost data will examine intermediate maintenance as a whole to include avionics and other subsystems. Each type of maintenance has its own unique circumstances which would impact any maintenance decision. This research attempts to explore the potential benefits of centralization across the entire intermediate spectrum. Both fixed and variable cost factors change depending upon specific maintenance tasks. Which areas offer the best potential for savings while maintaining combat effectiveness?

Section Four: Cost Comparisons

A Government Accounting Office (GAO) report published in 1979 advocated the centralization of Air Force intermediate maintenance. The report suggested that substantial savings could be realized in manpower, support equipment, and improved efficiencies (13:1-6). As noted earlier PACAF began centralizing its intermediate repair in late 1976 with positive results. The author sought to obtain cost data from PACAF units and USAFE units to make cost comparisons between the alternative structures. Data found during this search included intermediate support costs, initial spares costs, war reserve spare kits (WRSK) costs, replenishment spares costs, spare engine costs, and support equipment costs. Also obtained was the probable transportation costs

for shipping F110 engines. This additional cost was added to the total expense for any centralized structure.

In some cases the exact data was available; whereas, in others simplifying assumptions were made. Available studies from Synergy Incorporated and Technology Applications Incorporated provided the basis for some assumptions. Preference was given to obtaining variable cost data with little success. The only variable cost data found was from the Air Force's Visibility and Management of Operating and Support Cost (VAMOSC) program and the transportation costs. Since the simulation analysis was rigidly controlled, there was little fluctuation in these variable costs. The fixed costs chosen for inclusion directly fluctuate with maintenance concepts. The quantity of spares is crucial to any centralized structure. The need for additional spares to compensate for the additional pipeline times is a primary disadvantage of any centralized structure. Reduction in support equipment requirements is a principle plus for centralization. Each cost element will be presented and explained with emphasis on the primary differences between the two maintenance concepts.

Intermediate Support Costs

The VAMOSC system was established to provide aggregate cost data for Air Force managers. The rising cost of operations and support costs in the mid 1970's provided the impetus for establishing the VAMOSC program (9:1-5). Using

the F16 data from VAMOSC for fiscal year (FY) 1987, the overall maintenance support costs per flying hour for FY 87 averaged $1625 per hour. Making the assumption that intermediate maintenance accounts for one third of this cost, total intermediate cost would be $541.66 per flying hour. This represents a hypothetical average for all Air Force F16 units. To directly compare PACAF to USAFE F16 units, intermediate maintenance data was collected from Kadena from the first quarter of 1987 (87-1) for PW F100 engines. Also collected were F100 intermediate costs for F100 maintenance within USAFE. Within PACAF these costs equaled $19.96 per hour while in USAFE they equaled $29.94 per hour. Unfortunately this was the only quarter which reflected costs being attributed to Kadena AB for F100 support. The F100 data was checked by F100 experts to verify it consisted of only intermediate level tasks to enhance the cost comparisons. Based upon these cost ratios and upon Rand Studies, the author placed CIRF costs at a 20% savings below the overall Air Force average. This placed intermediate support costs at $433.32 for centralized structures and at $541.66 per flying hour for organic structures. The twenty percent savings rate is conservative compared to the 33% savings revealed by the F100 data. The twenty percent savings was cited by Rand in its analysis of PACAF's performance after implementing centralized maintenance.

Based upon these assumptions the combined savings within PACAF were as follows:

PACAF

PEACETIME:

(221 flying hours)(90 days)($108.34)=$2,154,882.60

WAR:

(442 flying hours)(30 days)($108.34)=$1,436,588.40

SUSTAINED:

(332 flying hours)(60 days)($108.34)=$2,158,132.80

PACAF TOTAL SAVINGS: $5,749,573.80

The realized savings with USAFE for centralized intermediate maintenance would be :

USAFE

PEACETIME:

(243 flying hours)(90 days)($108.34)=$2,369,395.80

WARTIME:

(486 flying hours)(30 days)($108.34)=$1,579,597.20

SUSTAINED:

(365 flying hours)(60 days)($108.34)=$2,372,646

USAFE TOTAL SAVINGS: $6,321,639

TOTAL OVERALL SAVINGS: $12,071,213

These potential savings represent the theoretical savings which would be realized from improved quality of maintenance, increased time between repairs, and improved

efficiency. The initial Rand studies cited improvements in reliability due to increased worker proficiencies. Although theoretical in nature, our available data supports our assumptions.

Transportation Costs

An additional cost incurred by centralized structures is the cost of transporting repairable items. To obtain an estimate of potential transportation charges, the Air Force's Military Airlift Command (MAC) was able to provide the round-trip transportation charges from Kadena to the F16 wings in PACAF and from Mildenhall AB in England to the F16 wings in USAFE (4). No transportation rates were available from Kemble AB to the chosen USAFE wings. Based upon these transportation rates and the number of F110 engine removals, the cost of shipping F110 engines was calculated. From this cost for F110 engines, an assumption was made that F110 engines represented 40% of all transport costs in peacetime and 33% of all costs during war and sustained operations. Based upon these assumptions, the total transportation charges were estimated as follows:

PACAF (TRANSPORTATION COSTS)

PEACE:	$377,064.39	
WAR:	$221,079.29	
SUSTAINED:	$332,132.29	
TOTAL ADDED COST:		$930,276.37

For USAFE the charges from Mildenhall to Ramstein were considerably cheaper. The estimates for USAFE were:

USAFE (TRANSPORTATION COSTS	
PEACE:	$256,343.13
WAR:	$150,283.00
SUSTAINED:	$632,357.32
TOTAL ADDED COSTS:	$1,562,633.70

These cost estimates fall within the Rand studies estimates for transportation costs. These added costs will be included in the comparisons made between centralized and organic structures.

Initial Spares

The initial spares estimates for centralized intermediate and organic intermediate came from a study being conducted by Synergy Incorporated for the Air Force. The Plateaus Study focuses on comparing when it makes sense to change maintenance structures. Based upon Synergy's mod-metric results for maintaining a 90% availability rate, the centralized structure required $38,225.35 per aircraft in initial spares for peacetime. These results added five additional days to the repair cycle for centralized bases to account for transportation requirements. The organic structure required $29,388.17 in initial spares (36). To tailor the Synergy results to this scenario, the assumption was made that the initial six month spare requirements would

be expended at a rate equal to the flying scenario. As a result the following table would reflect the actual expenditure of spares.

CENTRALIZED		ORGANIC
	PEACE	
$19,112.68		$14,694.09
	WAR	
$12,741.78		$9,796.06
	SUSTAINED	
$ 9,556.34		$7,347.04
$41,410.80	TOTAL COSTS	$31,837.19
TOTAL ADDITIONAL COSTS:		$ 9,573.61 (per A/C)

In essence the Synergy study identified spares requirements over an entire twenty year life of a weapon system. We adjusted these requirements to a fifteen year cycle and computed a peacetime expenditure rate. This peacetime rate was adjusted according to the flying schedule to compare relative costs for our scenario. The cost differential if absorbed entirely at the outset equals:

(Cost per A/C)(Cost per 180 days)=Total Life Cycle Cost

($9,573.61 per A/C)(30 times 180 days)=$287,208.30 per A/C

(237 A/C)($287,208.30)=$68,068,367

If the initial spares cost is absorbed over the first five years of the weapon system the initial cost is reduced

to $22,689,456. Given the importance of spares to a centralized structure, the assumption will be made that these costs are absorbed at the outset of the weapon system. These cost estimates do no include interest and assume costs are allocated equally over fifteen years.

WRSK Cost Comparison

The Synergy study served as the primary reference for WRSK cost comparisons. The Synergy study showed WRSK costs to be $496,032 per aircraft for a standard organic structure (36). The presence of prepositioned intermediate maintenance within forward theaters should reduce WRSK intermediate requirements. The author assumed a potential savings of 25% in WRSK requirements based upon Rand's CILC studies. Potential cost savings would be:

ORGANIC

(496,032 per A/C) (237 A/C) = $117,559,580

CENTRALIZED

(372,024 per A/C) (237 A/C) = $ 88,169,698

TOTAL SAVINGS: $ 29,389,896

The additional spares required by a centralized structure would also augment the initial surge of war. These initial WRSK costs also could be allocated over time. If these costs were allocated over five years their 180 day portion would equal $2,938,989.60. In the interest of readiness, they also will be absorbed at the outset.

Spare Engine Costs

Another significant cost difference between intermediate strategies is spare engine costs. If JEIM is centralized, additional spares are required to compensate for the increased repair cycle. Since this study focused on F110 engines, the relative costs of F110 spares were compared. Given the presence of 22 spare engines in PACAF for a centralized structure and 16 spare engines for organic JEIM, the difference in costs are detailed below:

PACAF (SPARE F110 ENGINES)

CENTRALIZED:	(22 Spares)($2,667,866 per engine)=	$58,693,052
ORGANIC:	(16 Spares)($2,667,866 per engine)=	$42,685,856
	TOTAL ADDED COST:	$16,007,135

Within USAFE, similar additional costs are incurred for centralization:

USAFE (SPARE F110 ENGINES)

CENTRALIZED:	(27 Spares)($2,667,866 per engine)=	$72,032,382
ORGANIC:	(18 Spares)($2,667,866 per engine)=	$48,021,588
	TOTAL ADDED COST:	$24,010,794
	COMBINED ADDED COST (PACAF/USAFE)	$40,017,929

This additional cost for centralized JEIM equates to $168,852.02 per aircraft more than for an organic JEIM

structure. This high cost represents a major investment and mitigates many potential savings of centralization. The added spares should provide competitive combat capability for a centralized structure (26:1-10).

Replenishment Spares

In addition to estimating initial spares requirements, the Synergy "Plateaus Study" estimated replenishment spares. The Synergy study estimated replenishment spares at $6.05 million per aircraft over the entire life of the weapon system (26:5). This cost estimate does not include either engines or support equipment. If these costs are allocated equally over a fifteen year life cycle, they equal $403,333 per year. For a 180 day scenario, the costs would be $201,667 per aircraft. Using this figure as an estimate, and PACAF studies, an overall replenishment spares cost was calculated. In PACAF, supply planners estimate a 12% increase in replenishment spares for a dispersed maintenance structure. The advantages of push distribution and centralized control over assets reduces recurring spares requirements. Based upon these assumptions, the following cost estimates were calculated:

PACAF (REPLENISHMENT SPARES)

ORGANIC:	($201,667 per A/C)(113 A/C)=$22,788,371	
CENTRALIZED:	($177,467 per A/C)(113 A/C)=$20,053,771	
	TOTAL SAVINGS:	$2,734,600

These potential savings represent an estimate of what might be saved over the 180 day scenario for replenishment spares. No adjustments were made for wartime or sustained increases.

USAFE (REPLENISHMENT SPARES)

ORGANIC:	($201,667 per A/C)(124 A/C)=$25,006,708	
CENTRALIZED:	($177,467 per A/C)(124 A/C)=$22,005,908	
	TOTAL SAVINGS:	$3,000,800
	COMBINED SAVINGS:	$5,735,400

The potential $5,735,400 in savings represents a hypothetical savings of centralization. Centralized asset control and improved supply visibility are perceived benefits of centralization. No adjustments to these totals were made for surge operations because of airlift constraints. In all likelihood, wartime resupply will take several months to occur.

Support Equipment Costs

The final category of cost which will be examined will be support equipment. The F16 SPO contracted with Technology Applications Incorporated to assess support equipment requirements for PACAF and USAFE F16 units. The contract study provided the table of allowance authorizations for centralized intermediate maintenance in PACAF as well as for an organic structure. Based upon these table of allowances, and the organic support equipment

requirements for USAFE, cost estimates were made. To determine the potential savings, the assumption was made that organizational level equipment would be the same in USAFE as in PACAF. Based upon this computation, the overall cost difference between the maintenance structures was calculated. The support equipment was divided into different categories. These categories were avionics, engines, and others. The overall savings were calculated for both PACAF and USAFE. The cost figures are provided below:

F16 SPO STUDY

PACAF SUPPORT EQUIPMENT REQUIREMENTS

	CENTRALIZED	ORGANIC
AVIONICS		
	$51,421,298	$60,047,352
ENGINES (F110)		
	$10,118,121.92	$9,229,957.92
OTHER		
	$20,772,669.18	$43,457,492.12
TOTALS		
	$82,312,089.10	$112,734,801.04
PACAF SAVINGS:		$30,420,711.94
TOTAL SAVINGS PER AIRCRAFT:		$269,209.83

USAFE SUPPORT EQUIPMENT REQUIREMENTS

AVIONICS (ORGANIC)

RAMSTEIN (48 PAA)	TORREJON (72 PAA)
$18,393,944	$36,560,726

ENGINES (F110)

$4,792,059.16	$8,174,778.44

OTHER

$35,581,148.08	$53,157,470.65

TOTALS

$58,767,152.04	$97,892,975.09
USAFE TOTAL (ORGANIC):	$156,660,127.13
SUPPORT EQUIPMENT PER A/C:	$1,263,388

USAFE SUPPORT EQUIPMENT

CENTRALIZED (ESTIMATES)

AVIONICS:	$51,604,131
ENGINES (F110):	$21,469,794
OTHER:	$44,096,223
TOTAL SUPPORT EQUIPMENT:	$117,170,148
SUPPORT EQUIPMENT PER AIRCRAFT:	$944,920
TOTAL USAFE SAVINGS:	$39,489,981

Based upon PACAF's organizational equipment requirements, potential savings for USAFE were calculated. PACAF's total intermediate requirements for an organic structure equaled $59,234,981. Based upon this figure, USAFE's potential savings under a centralized maintenance structure would be $39,489,983 (29:1-3). In essence, centralized would eliminate the additional intermediate equipment for the second wing. From the previous results, it should be noted that this represents a conservative estimate. Overall support equipment costs are higher in USAFE than in PACAF. This fact may be due to wartime taskings, peacetime priorities, or funding support. Whatever the cause, centralization would offer significant savings. Another fact which should be pointed out is that centralization provides no savings in F110 maintenance support. From the cost data provided, it is clear that avionics offers a clear opportunity for savings. This fact highlights the need to evaluate different maintenance functions independently. Obviously an "all or nothing" approach is not appropriate for intermediate level maintenance. Some maintenance functions may be more appropriate for centralization than others.

Overall Cost Summary

The overall cost comparisons for alternative maintenance strategies is summarized below. Does centralized intermediate maintenance really save money? The costs have

been combined for the study's specific 180 day scenario. Cost elements which are included are intermediate support costs, transportation costs, initial spares, WRSK, replenishment spares, spare F110 engines, and support equipment costs. The cost estimates are combined for both PACAF and USAFE and a plus (+) sign represents a savings of centralization; whereas, a minus (-) represents an added cost of centralization. Overall cost totals were:

COST IMPACTS OF CENTRALIZATION

INTERMEDIATE SUPPORT	+$12,071,213
TRANSPORTATION CHARGES	-$ 1,562,631
INITIAL SPARES	-$68,068,367
WRSK KITS	+$29,389,896
SPARE F110 ENGINES	-$40,017,929
REPLENISHMENT SPARES	+$ 5,735,400
SUPPORT EQUIPMENT (PACAF)	+$30,420,711
SUPPORT EQUIPMENT (USAFE)	+$39,489,983
TOTAL SAVINGS	+$ 7,458,276

The total savings in the cost calculations represent a small percentage relative to the overall costs. The bulk of the cost trade-offs are from the spares requirements for centralized maintenance and for support equipment in organic structures. The purchase of spares compensates for the lack

of repair capability at the wings. On the other hand, the tremendous cost of support equipment makes organic structures very expensive. The minor cost difference probably would not be a decision driver. Perhaps an alternative structure could combine positive attributes of both structures. The obvious advantage of centralization in support equipment offers potential savings. Local repair in organic structures reduces costly spares requirements. Logistics planners must attempt to combine these positive aspects into a single support structure.

Section Five: Overall Analysis

The overall results provide some general conclusions. On balance, organic JEIM provides substantial improvement in aircraft availability over centralized JEIM during war and sustained environments. The cumulative impact of increased pipeline times quickly consumes the additional spares provided for centralized structures. Peacetime performance on the other hand is not significantly different. Overall organic JEIM provided an additional 1,974 aircraft for the 180 day scenario. This total represents a 4.6% increase in overall aircraft availability. The bulk of these aircraft are provided during the sustained portion of the scenario. This fact illustrates the impact of localized repair on sustained combat capability.

The estimated additional cost of $7,458,276 represents a very small increase. In fact this difference accounts for

less than three additional F110 engines. An important fact to note is that these cost estimates attempt to combine all intermediate level maintenance. The JEMS model only evaluated JEIM support. If the JEIM results are representative of overall intermediate maintenance, many conclusions can be made. The many unique aspects of avionics, engines, and other maintenance functions makes this conclusion questionable. Each maintenance function would require independent performance and cost analysis. From this study's results, one can definitely determine that organic JEIM provides increased capability at substantially the same cost as centralized JEIM.

Summary

This chapter presented the simulation results on aircraft availability for centralized and organic JEIM. The availability results were statistically analyzed for the relative differences in performance. Cost data was presented which detailed the relative economies of the alternative structures. Finally an overall assessment of the research results were presented. The following chapter presents the study's overall conclusions.

V. Conclusions

Chapter Overview

This chapter provides conclusions about the research results from Chapter IV. The aircraft availability results and cost comparisons are summarized. Overall trends within the results are explained and examined for further relevance. Finally, those areas displaying the greatest potential are highlighted.

Research Limitations

The broad nature of intermediate level maintenance required this study to limit its scope. The JEMS model was used to evaluate F110 intermediate maintenance under both a centralized and a traditional structure. The performance results in this study relate exclusively to engine support. The assumption has been made that JEIM is representative of overall intermediate maintenance.

Research time constraints and limited expertise made this assumption necessary. The cost estimates made were for overall intermediate level maintenance. The extent to which F110 intermediate maintenance is representative of overall intermediate maintenance directly impacts the research validity. The simulation results and actual peacetime availability rates are similar, but multiple factors impact "actual" performance results. The scenarios chosen for

research analysis were rigidly controlled. Only those elements directly pertinent to maintenance structure were allowed to differ. These elements were transit times, spares, maintenance crews, and maintenance resources. The relative performance of JEIM support was evaluated under these conditions.

The cost estimates included only portions of overall maintenance costs. Simplifying assumptions made by the author make the cost estimates "rough approximations" of comparative costs. Similar studies completed by the Rand Corporation and Synergy Incorporated offer credence to the overall cost estimates.

The multitude of factors which impact maintenance support make detailed analysis difficult. This study explored the potential impact of centralization upon mission capability and cost. Despite the limited scope of the study, some general conclusions were made. The most significant results follow.

Aircraft Availability

Aircraft availability results for F110 support produced mixed results. Little statistical difference between performance results was observed for peacetime scenarios. Only when the repair cycle was increased by 25 percent did major differences occur. This fact suggests that centralized JEIM is more sensitive to time. The fact that centralized JEIM allows less flexibility is an important

point. The built-in transportation requirements make centralized JEIM less responsive to change.

The general conclusion that can be made about peacetime operations is that either concept provides adequate support. If transit times are reduced from four days to two days, centralized JEIM shows only minor improvement. Factors such as maintenance crews, spares, and test cells often are the limiting constraint.

Wartime Conclusions

The most evident difference between centralized JEIM and organic JEIM again appeared in the increased repair cycle scenario. As mentioned earlier, this scenario is the most realistic. Maintenance crews were the source of maintenance backlogs in both cases. Since both structures had equal manning levels, the results reflect the impact of transportation times. In USAFE, centralized JEIM provided more aircraft for both the five and six day scenarios. This suggests that the additional spares under centralized JEIM overcame the transportation requirements. These mixed results show that centralized JEIM can provide comparable support, but that the impact of increased repair times could be drastic. Probable wartime conditions make this impact risky. The negative impact of increased repair times makes centralized JEIM unacceptable for war.

Sustained Conclusions

The sustained scenario results vividly depict the negative impact of centralization. Over time aircraft availability declines and reveals a relative advantage for organic JEIM. The results were particularly evident in PACAF with only one exception in USAFE. Increasing spares produced little change while increasing crews in PACAF gave centralized JEIM an advantage for three scenarios. Once again, the increased repair cycle gave organic JEIM the clear advantage. These results suggest that maintenance crews may prove to be the limiting factor. Reducing transit times may prove irrelevant if maintenance capacities are exceeded.

Availability Summary

Maintenance strategies and organizational structures directly impact performance. The maintenance concept's ability to provide effective logistics support is dependent upon providing sufficient quantities of people, spares, and repair capabilities. The JEMS model indicates that centralized JEIM can provide comparable support for peacetime scenarios. The unpredictable nature of wartime repair cycles dictates the use of organic JEIM for war and sustained operations. Graphs provided in Appendix F illustrate worldwide availability results and relative maintenance performance. The trade-off of spares for people

limits flexibility and reduces responsiveness. The positive impact of centralization upon mobility was not directly examined. Based upon the JEMS simulation results, organic JEIM has clear advantages. This study assumes the wings will conduct all operations from their home bases. The interruptions caused by deployment would drastically change these results. Current plans call for little intermediate support during the first thirty days of war. Prepositioned CIRF's with intermediate capability immediately available would offer clear advantages.

In essence, centralized JEIM is not as effective as organic JEIM. Local repair capability provides greater combat capability. The impact is minimal in peacetime but can be very substantial during wartime contingencies.

Cost Comparison

The principle differences in costs between the intermediate concepts is support equipment and spares. Organic repair requires a great amount of support equipment; whereas, centralized repair compensates by purchasing additional spares. In essence, there is little total difference. Only minor operating efficiencies were noted from the VAMOSC data. Given the greater combat capability of organic repair, preference for that concept is clearly warranted.

A principle purpose for this research has been the balancing of wartime effectiveness with peacetime

efficiency. The small amount of savings offered by centralization requires little balancing. While other subsystems such as avionics may offer greater relative savings, JEIM clearly does not.

Overall Conclusion

Logistics support decisions require a combined systems approach. Based upon combat capability and cost considerations, F110 intermediate support should be collocated with operational units. The increasing costs of maintenance support may ultimately dictate the location of CIRFs with operational units. Given this study's results, centralized JEIM offers little savings at a great cost in mission capability.

VI. Discussion and Recommendations

Chapter Overview

This chapter concludes the study by discussing the research results and making recommendations for future studies. Potential ramifications of the research results are explored in light of current trends within Air Force maintenance policies.

Discussion

The results of this study validate the preference of Air Force leaders for unit "self sufficiency". The net cost of this operational strategy does not appear to be prohibitive. The exchange of repair capability for additional spares limits combat flexibility and offers little savings. Peacetime performance results reveal little difference but surge demands reveal inherent weaknesses for centralized support. This study assumed that JEIM support was representative of all intermediate support. More detailed and functional analysis would be required for different types of maintenance. Crucial to any scenario would be the economic viability of purchasing sufficient spares. Resource constraints often create shortfalls within Air Force spares. Without sufficient spares, centralized repair detracts from readiness. Another related aspect is that local repair remains subject to local commanders.

Centralized repair facilities fall outside the direct control of wing commanders. These facts detract from a wing commander's control while still retaining his responsibility for mission performance.

Another factor would be unit identification. Personnel assigned to flying wings hopefully identify with unit performance and see their individual contributions. Being physically present at the unit should enhance this recognition and provide job motivation.

Transition to War

Given the equal performance of the maintenance strategies during peace, what should be done? Is it possible to combine the best attributes of both strategies? Historically armies have preferred to operate and train in peace as they intend to fight in war. If this tradition remains, it becomes very difficult and unnecessary to combine both strategies. Current trends of improved component reliability, airlift shortages, and rising support equipment costs require a change in thinking. Decreased DOD funding requires the development of alternative maintenance structures. If vulnerability issues dominate, perhaps the strategies should be implemented within the United States. Rising support costs limit military options and decrease overall military capability.

Logistics planners must design logistics systems which recognize the growing development of diagnostic systems and

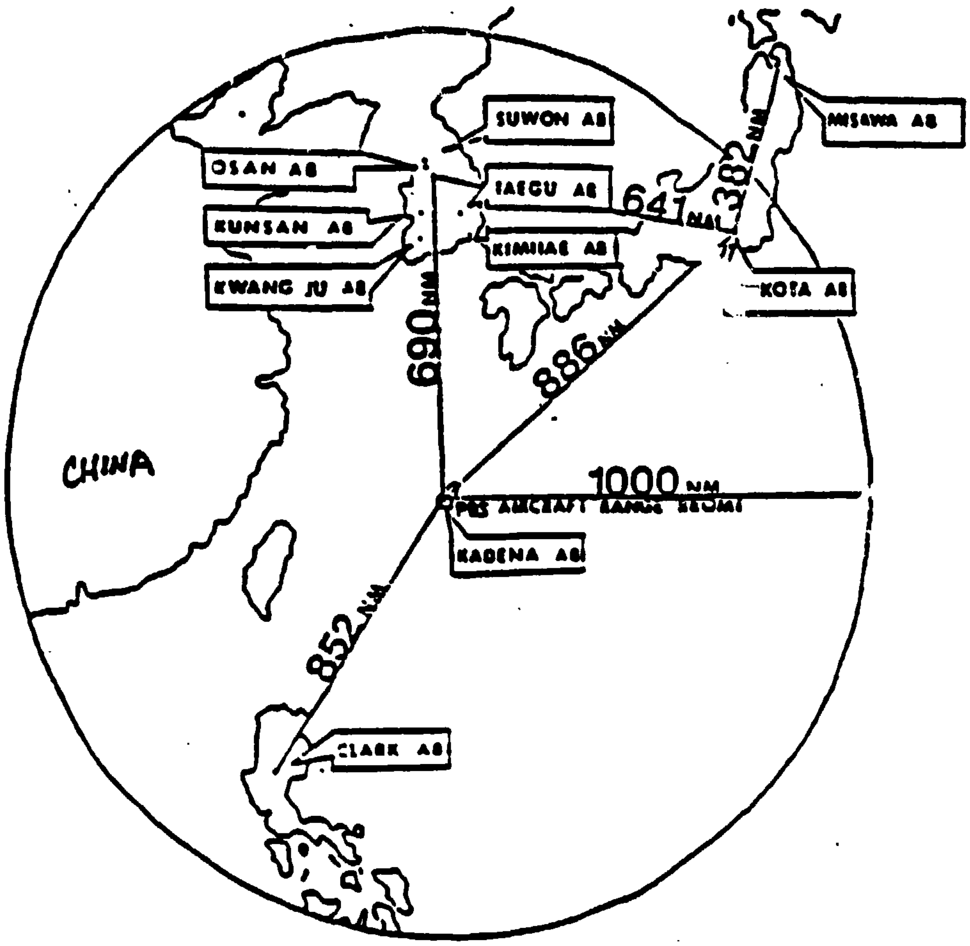
the impact of increased technical complexity. Retaining repair capability at the unit level may gradually become too costly and inefficient. Future weapon systems must recognize these trends and take steps now to meet the challenges which lie ahead.

Future Research

This study has evaluated one weapon system for one type of intermediate maintenance. Further research is required on existing weapon systems to highlight potential impacts of centralized intermediate maintenance. The ideal time for implementing alternative maintenance concepts comes at the initial acquisition of a weapon system. Existing systems can provide data and information about the best strategies for tomorrow's weapon systems. Increased reliability, computer technology, and personnel proficiency all will directly impact future maintenance strategies. Those who do not understand the mistakes of the past are likely to repeat them again in the future.

Appendix A: Operating Locations Supported

OPERATING LOCATIONS SUPPORTED



Appendix B: PLSC Supported Aircraft

	AUTH
* 3TFW CLARK AB, RP	
F-4E/G	48
F-5	11
* 8TFW KUNSAN AB, KOREA	
F-16	48
* 18TFW KADENA AB, JAPAN	
F15C/D	72
RF-4C	18
* 51TFW OSAN AB, KOREA	
F-FE	12
OV-10	16
* 6151 CAMS SUWON AB, KOREA	
A-10	24
* 6497 CAMS TAEGU AB, KOREA	
F-4E	12
* 432TFW MISAWA AB, JAPAN	
F-16	48
TOTAL AIRCRAFT SUPPORTED	309

Appendix C: Interview Questions

1) What impact did centralization have on PACAF's combat capability?

2) How would centralized intermediate maintenance at Kadena impact PACAF's wartime capability?

3) What were some negative and positive outcomes for establishing the CIRF at Kadena?

4) What things could have been done to improve the centralized concept?

5) Did PACAF save money by centralizing intermediate repair?

6) Given the choice, which intermediate maintenance structure would you prefer?

Appendix D: Engine Pipeline Standards

ENGINE PIPELINE STANDARDS
F110-GE-100

	PEACE	SURGE	SUST
BASE REPAIR CYCLE			
REMOVAL TO START WORK	2	2	2
IN WORK	16	8	10
DEPOT REPAIR CYCLE			
REMOVE, INSPECT, PROCESS, SHIP	2	2	2
TRANSPORTATION (CONUS/USAFE/PACAF)	3/8/9	3/8/9	3/8/9
DEPOT RECEIVING	1	1	1
WORKLOAD	4	4	4
IN WORK	61	29	37
ARBUT			
BASE NOTICE TO SHIPMENT	4	4	4
TRANSPORTATION (CONUS/USAFE/PACAF)	3/8/9	3/8/9	3/8/9
RECEIPT TO START WORK	1	1	1
BUILDUP	1	1	1
DRC + ARBUT	80/90/92	48/58/60	56/66/68

Appendix E: List of Maintenance Assets (JEMS Inputs)

CENTRALIZED JEIM (BASELINE)

	PACAF	USAFE
MAINTENANCE CREWS:	16	21
SPARE F110 ENGINES:	22	27
TEST CELLS:	2	2
ROLLSTANDS:	4	4
HARDSTANDS:	36	36
CMRI (Removal Interval)	229 (Peace)	312.5 (Others)

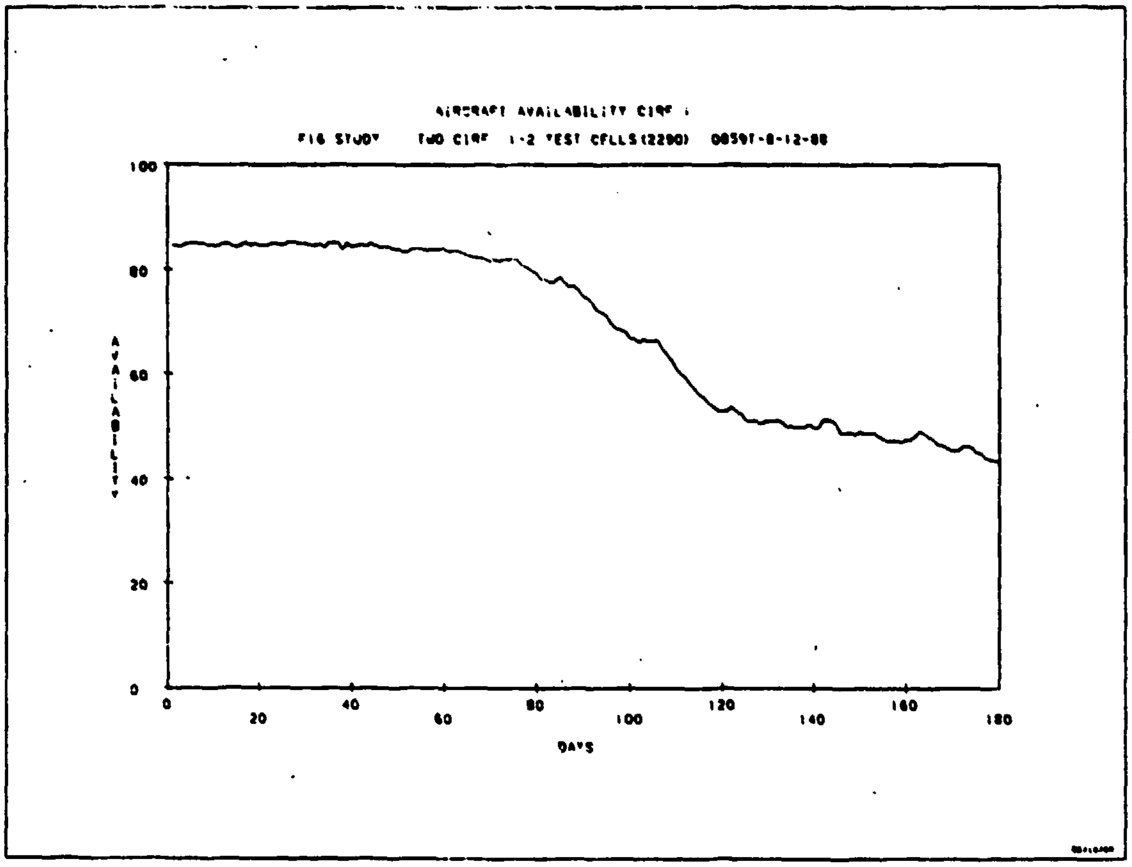
ORGANIC JEIM (BASELINE)

	PACAF	USAFE
MAINTENANCE CREWS:	16	21
SPARE F110 ENGINES:	16	18
TEST CELLS:	4	4
ROLLSTANDS:	4	4
HARDSTANDS:	48	48
CMRI (Removal Interval):	229 (Peace)	312.5 (Others)

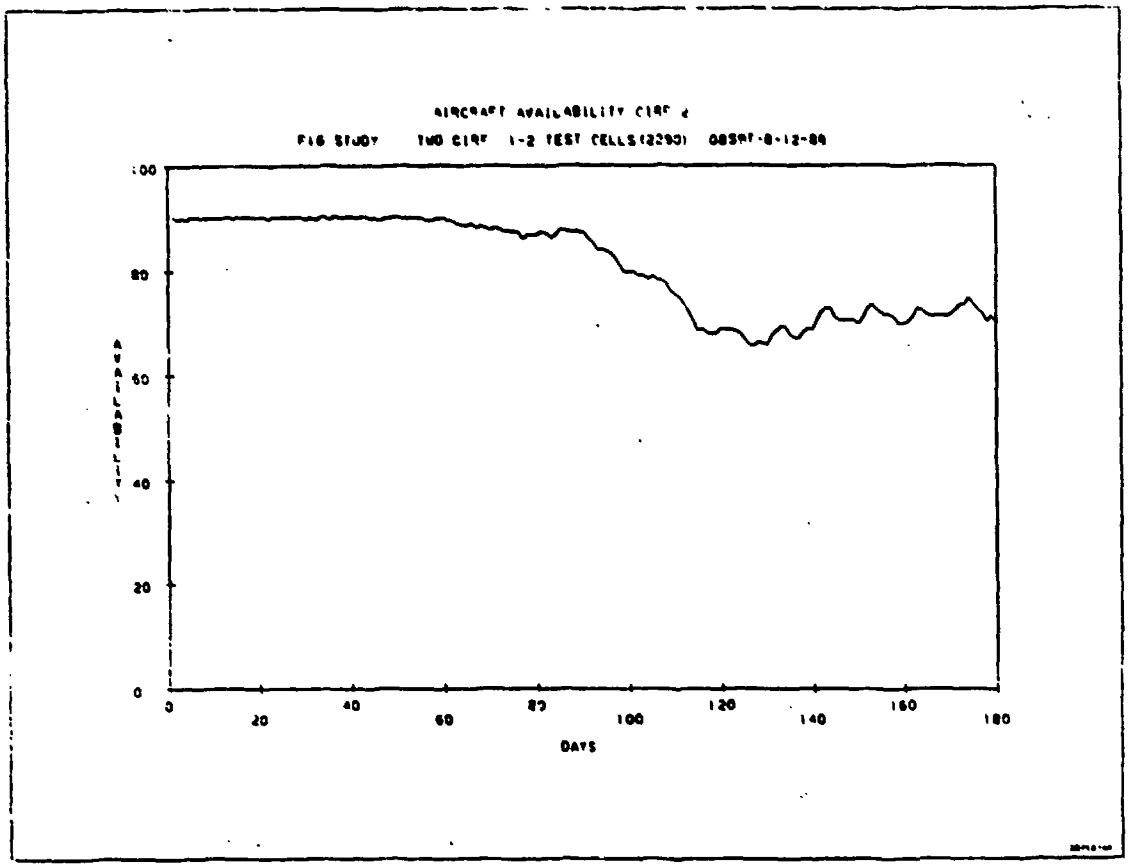
Appendix F: Graphical Results

This appendix provides selected graphs from the JEMS simulation results. Availability rates for PACAF and USAFE wings are presented for both JEIM intermediate structures. Results presented are the two days transit, four days transit and the increased repair cycle. Most revealing is the graph revealing worldwide serviceable engines. This graph reveals the point where centralized JEIM depletes its spare F110 engines. Its occurrence during the wartime portion of the simulation has direct impact on mission capability.

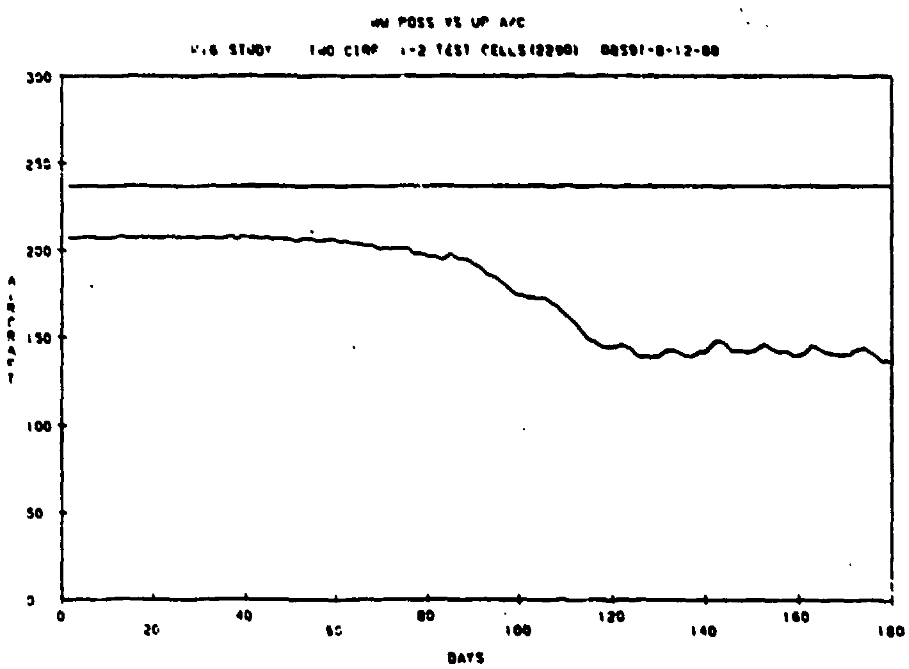
PACAF CENTRALIZED JEIM (2 DAYS TRANSIT)



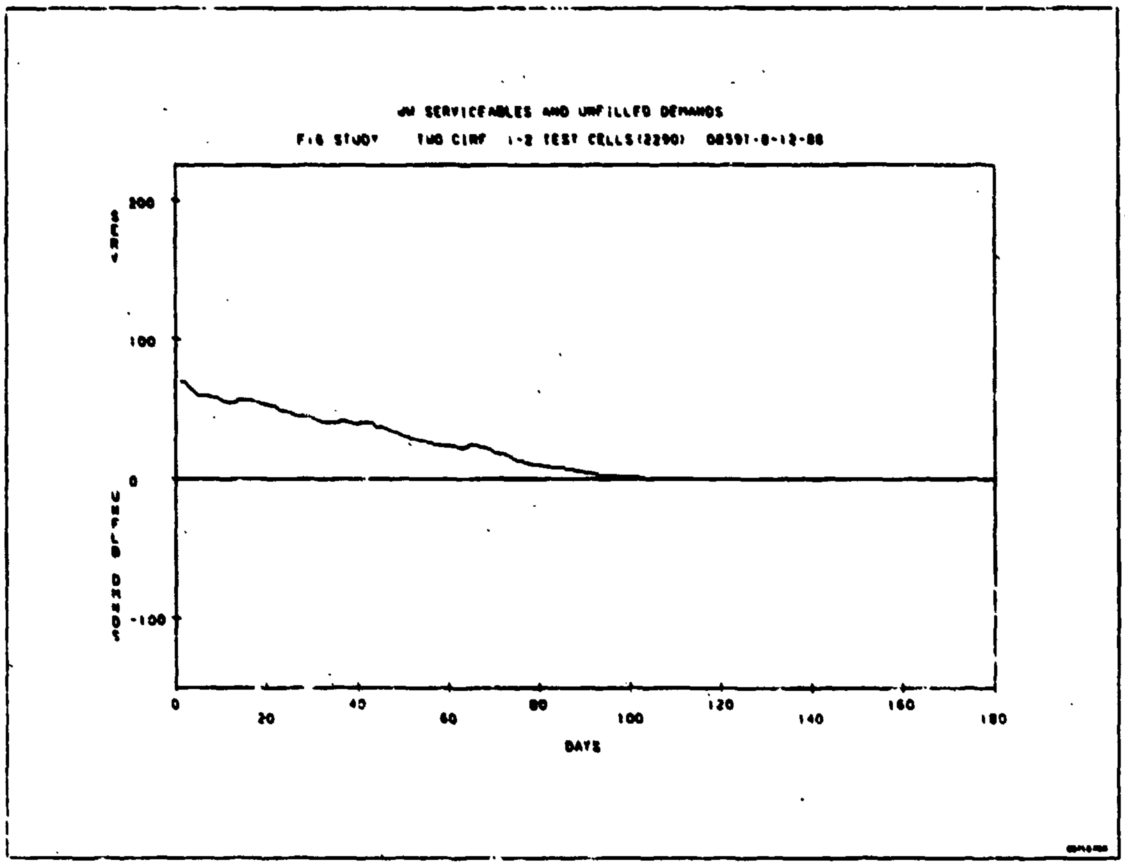
USAFE CENTRALIZED JEIM (2 DAYS TRANSIT)



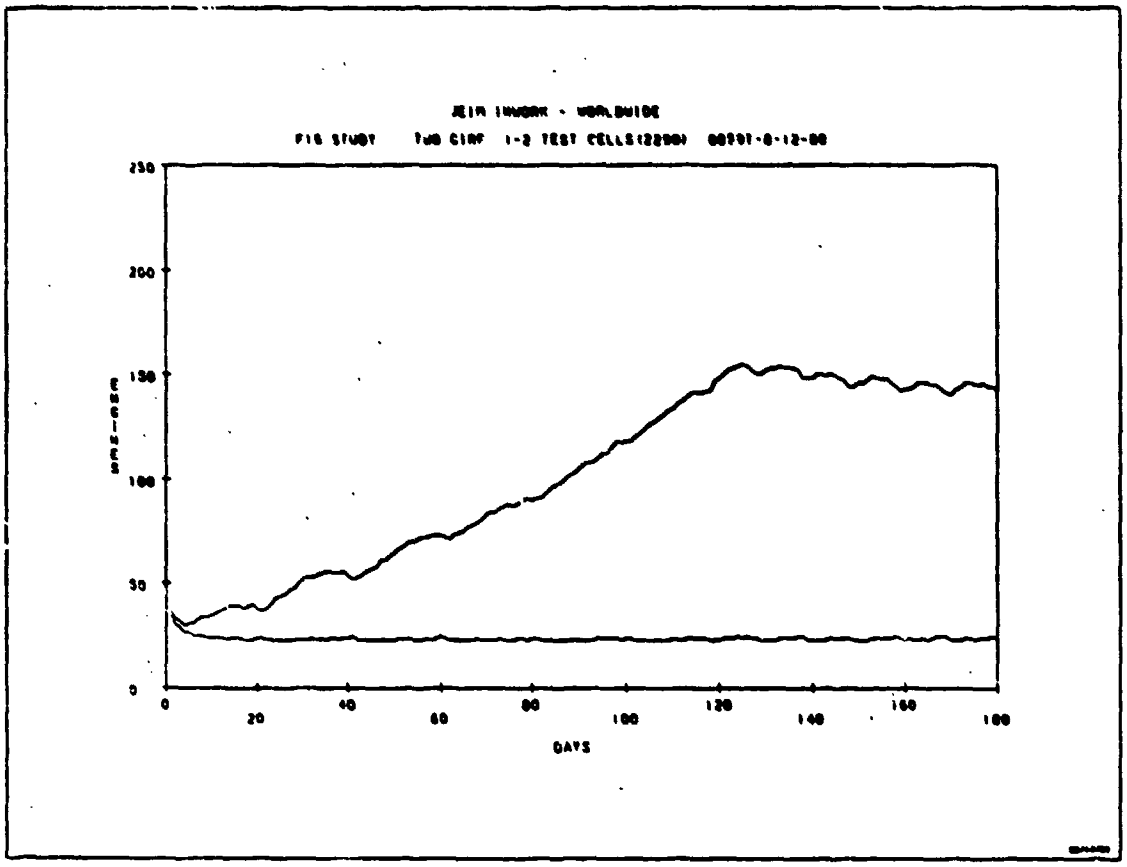
WORLDWIDE AVAILABILITY (2 DAYS TRANSIT)



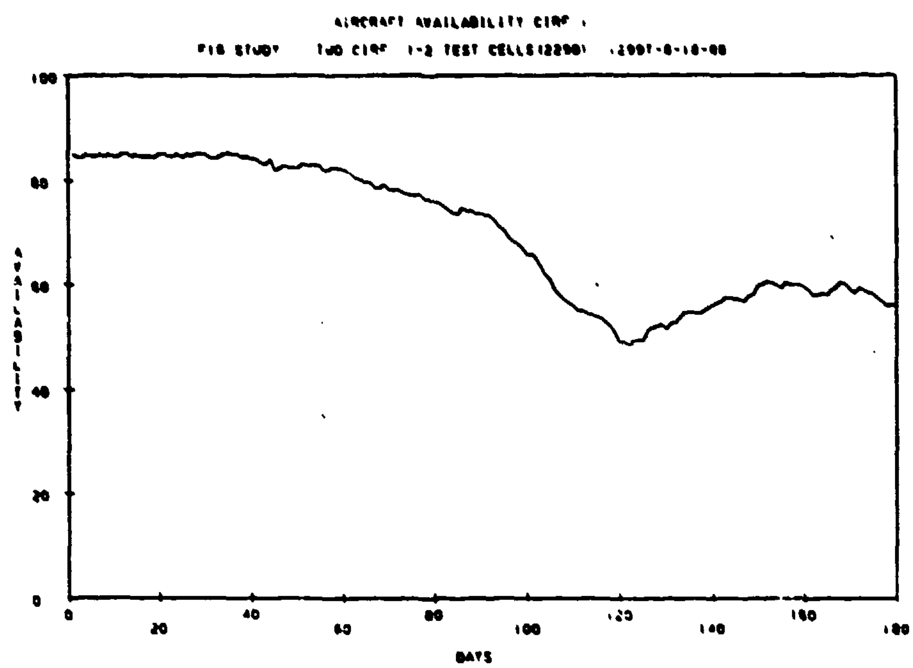
WORLDWIDE SERVICEABLES (2 DAYS TRANSIT)



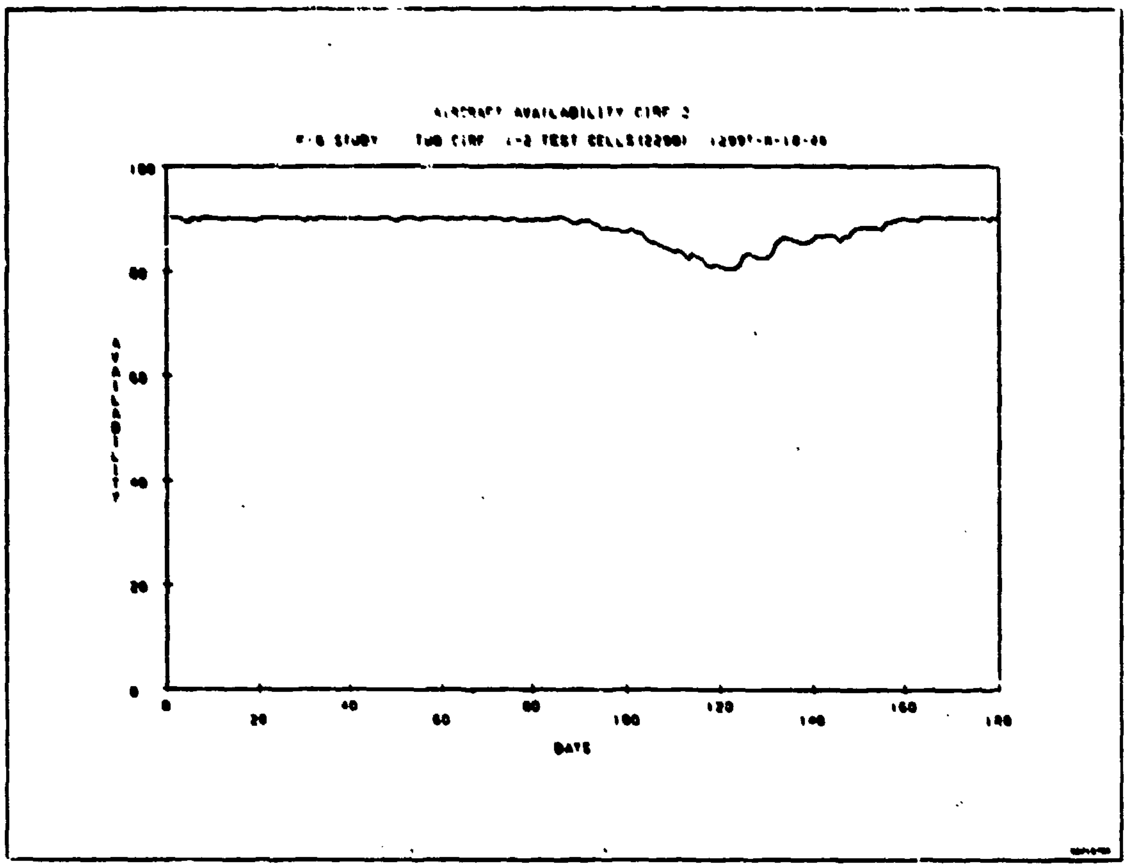
WORLDWIDE INWORK (2 DAYS TRANSIT)



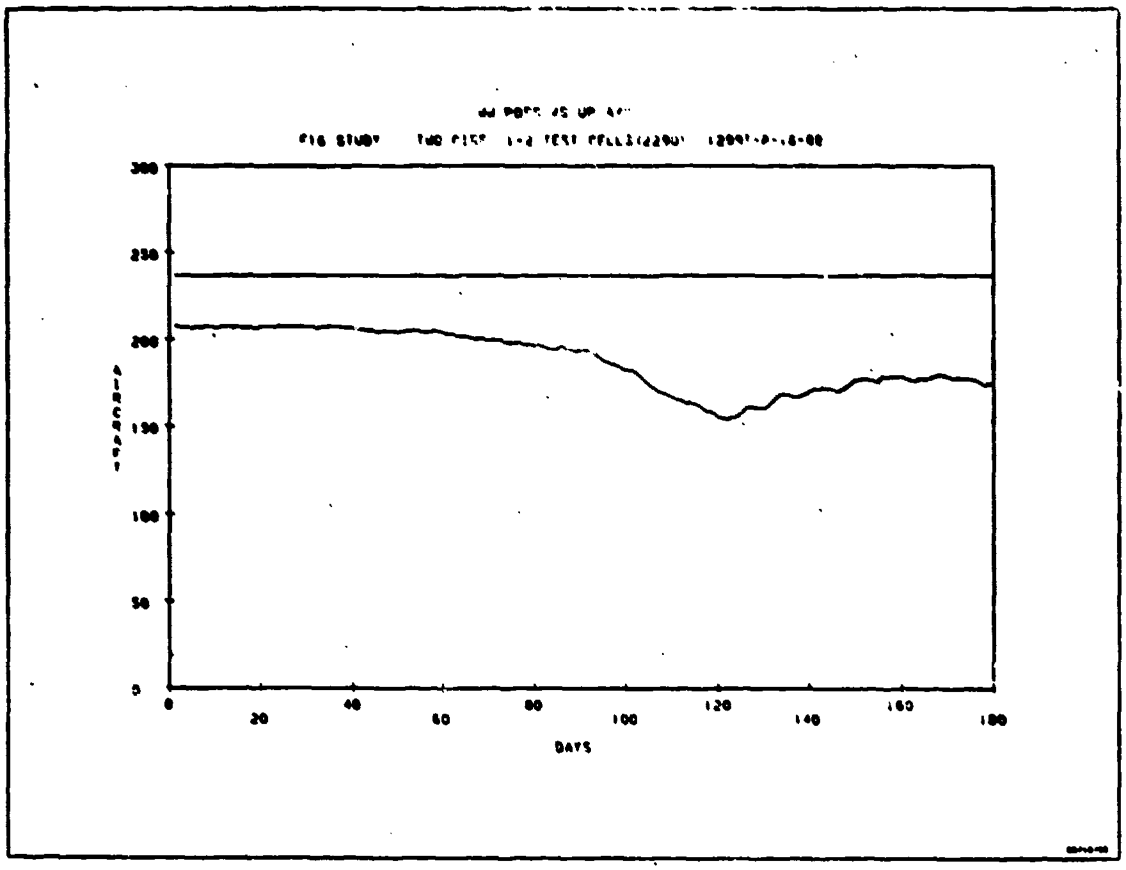
PACAF CENTRALIZED JEIM (4 DAYS TRANSIT)



USAFE CENTRALIZED JEIM (4 DAYS TRANSIT)



WORLDWIDE AVAILABILITY (4 DAYS TRANSIT)



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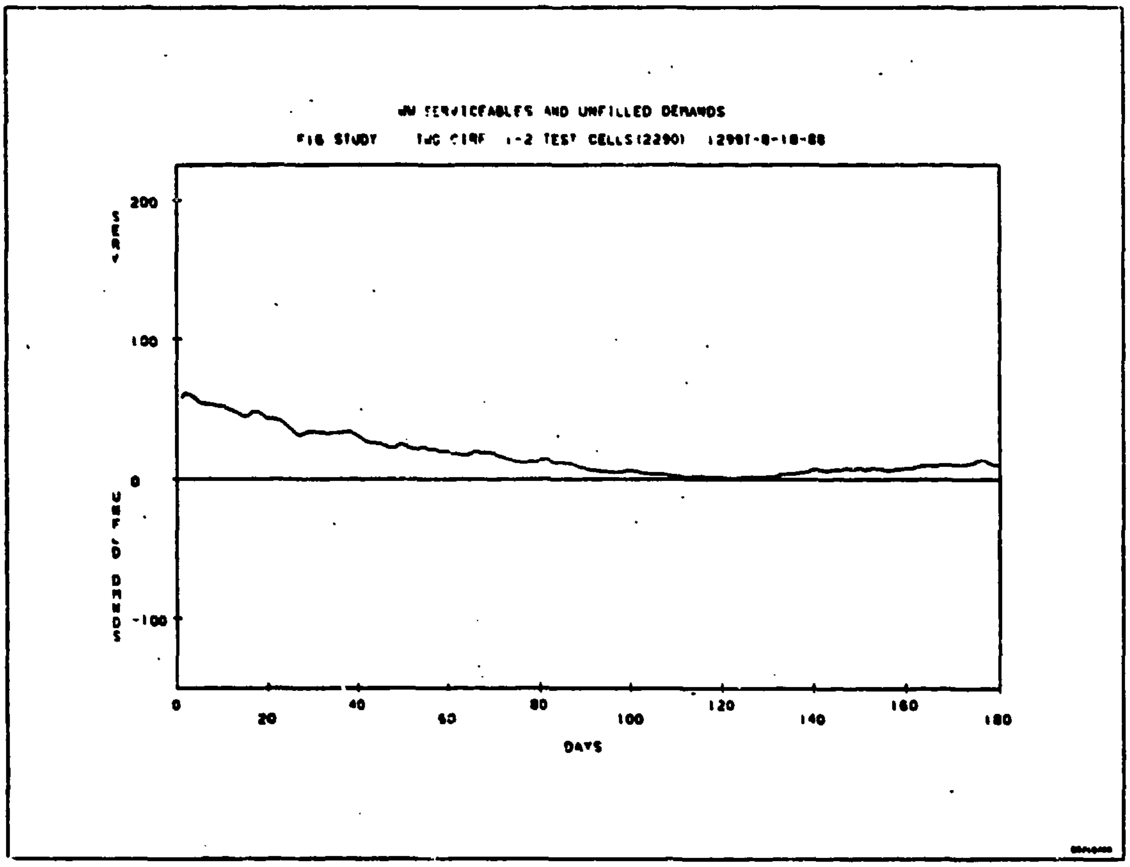

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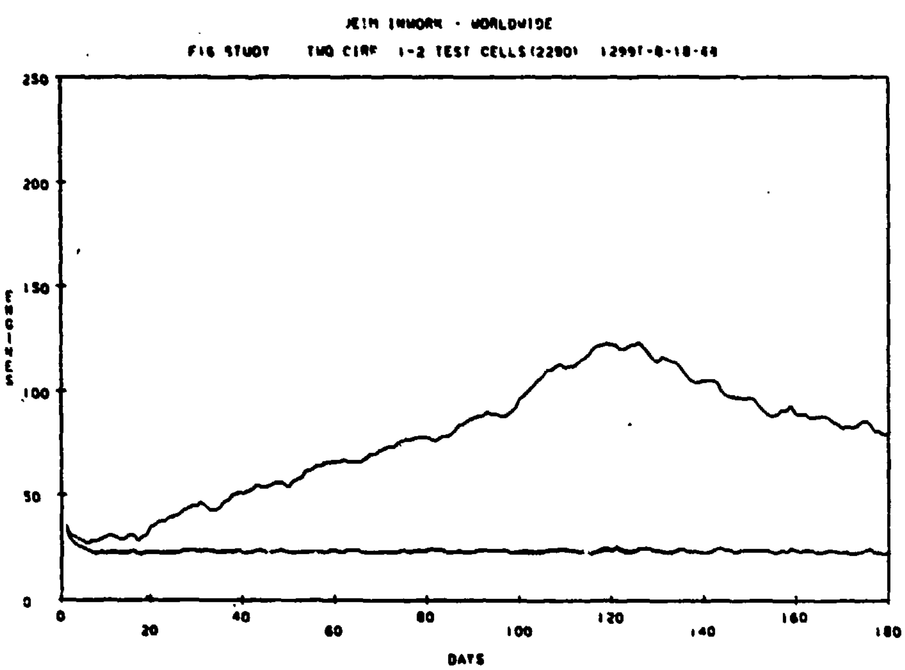
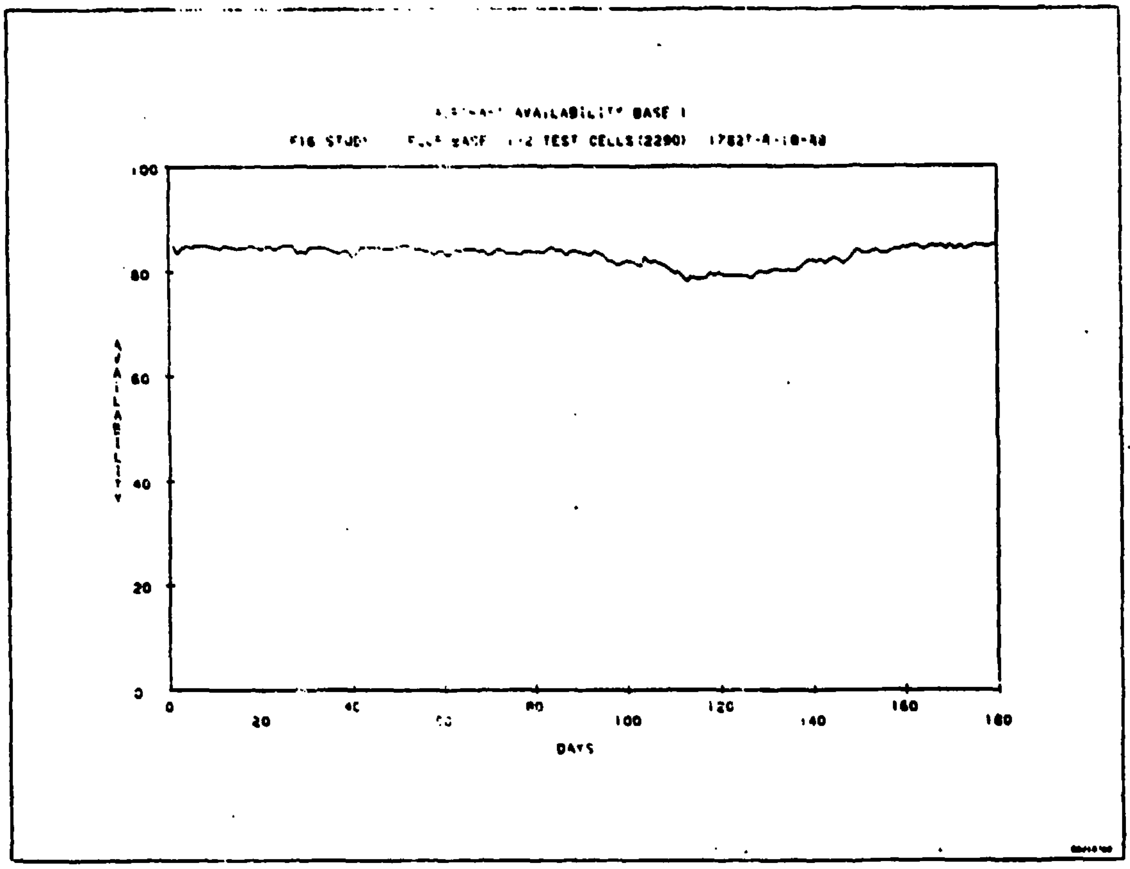
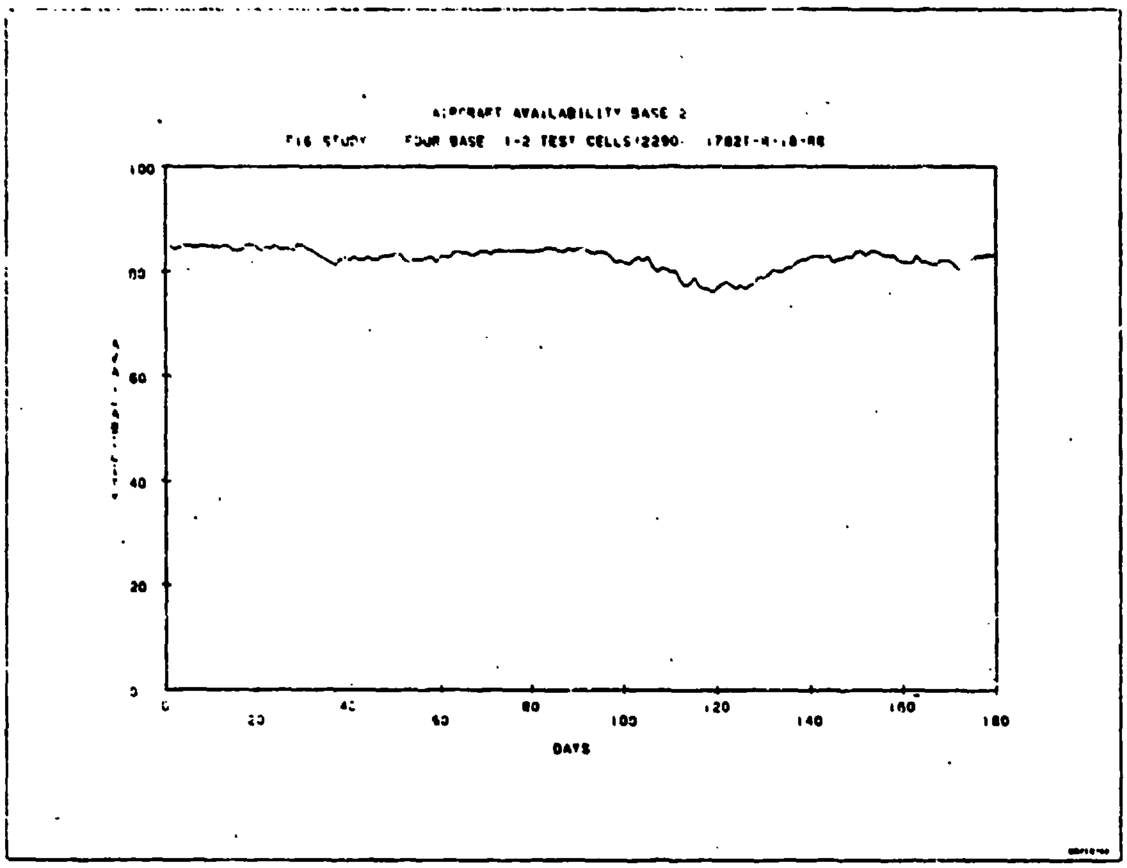


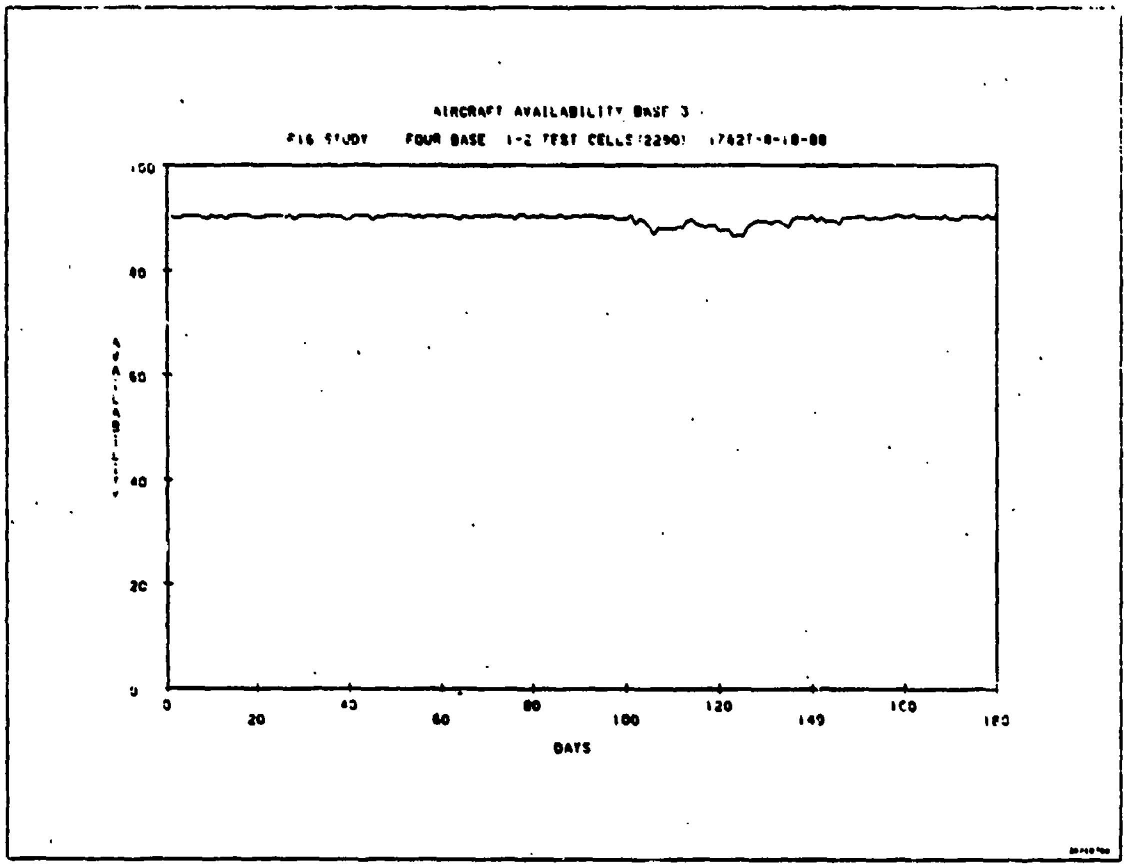
MISAWA AVAILABILITY (ORGANIC JEIM)



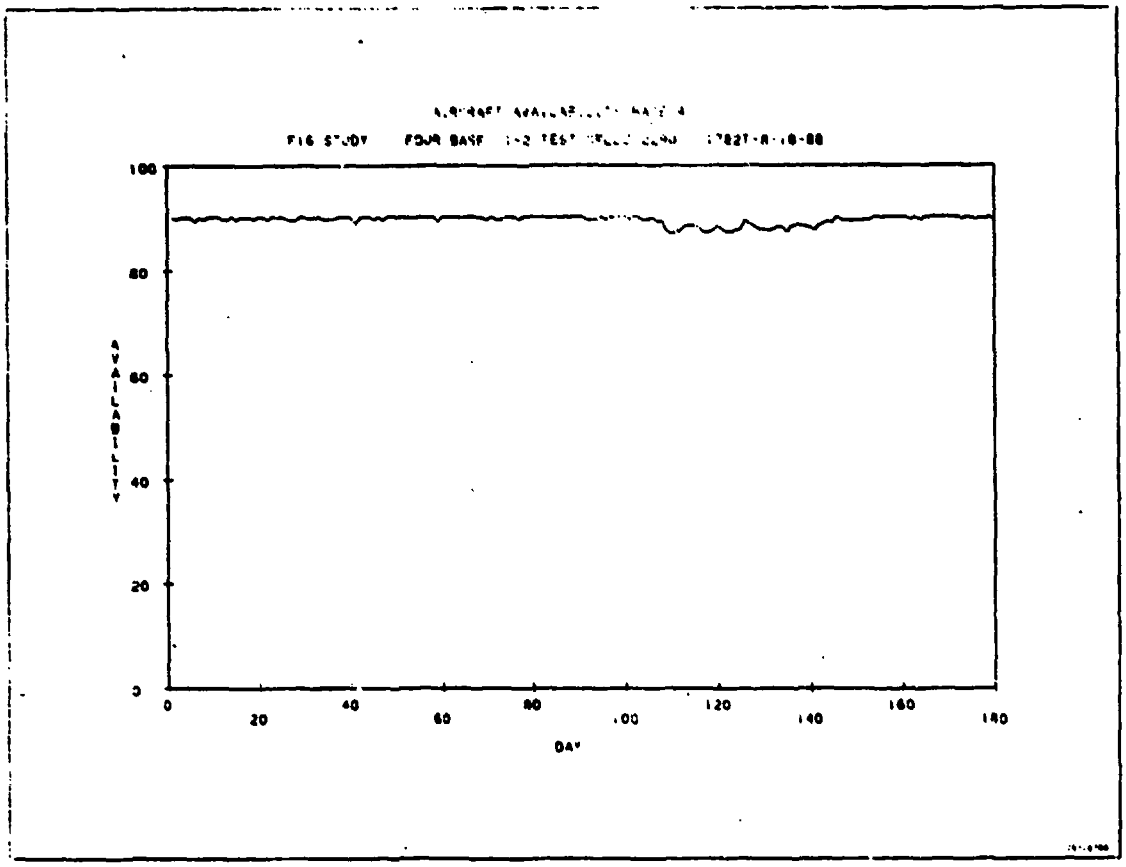
KUNSAN AVAILABILITY (ORGANIC JEIM)



RAMSTEIN AVAILABILITY (ORGANIC JEIM)



TORREJON AVAILABILITY (ORGANIC JEIM)



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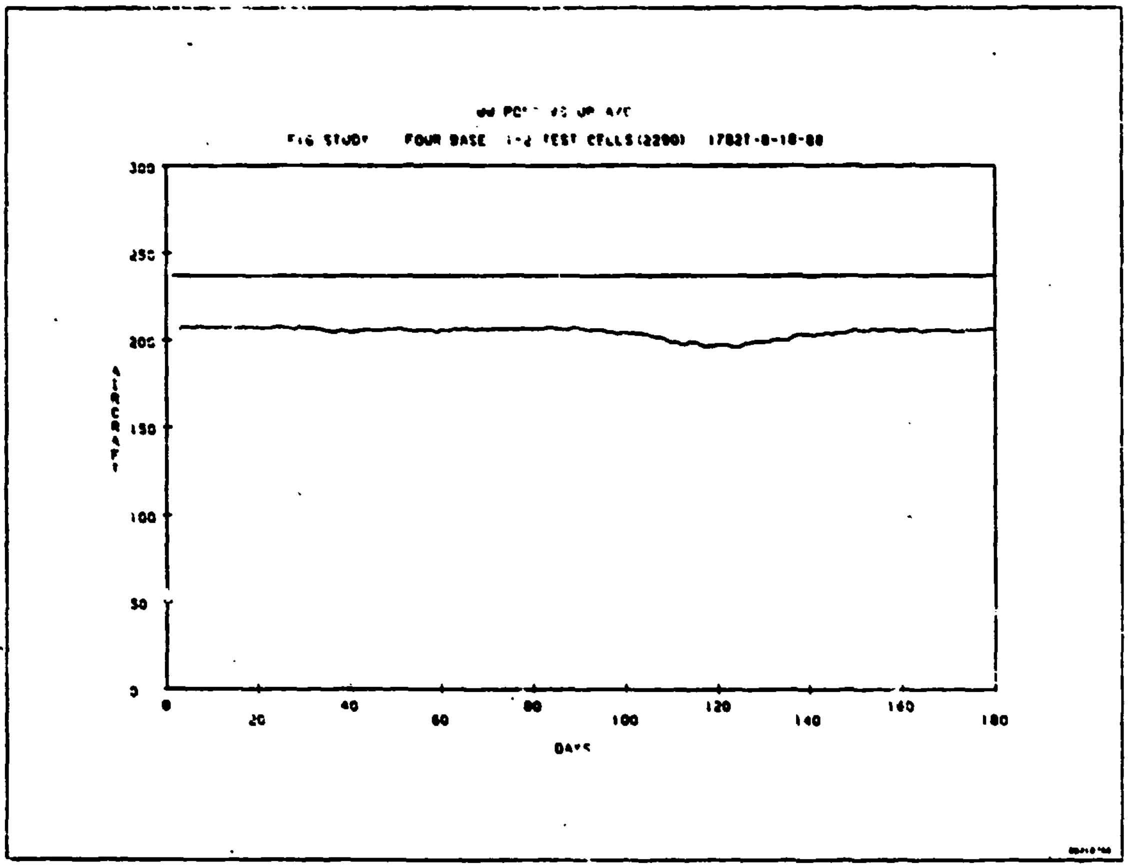

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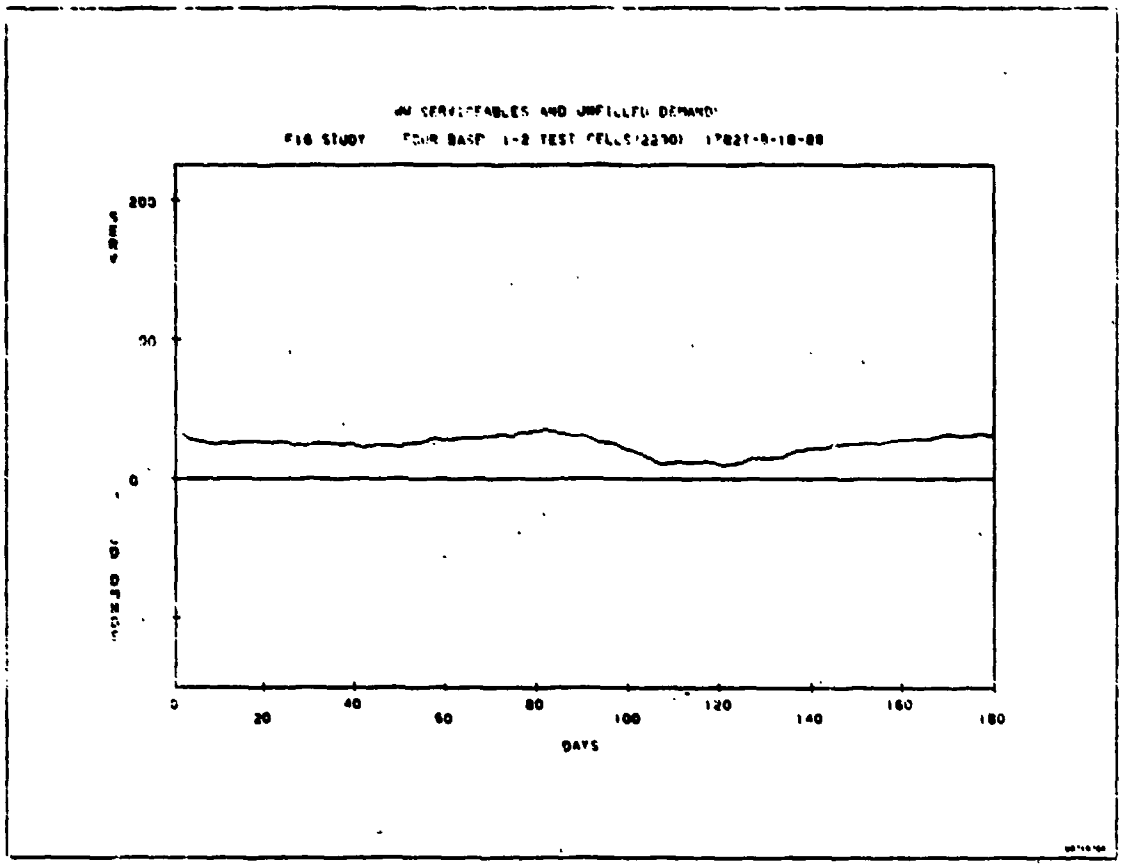
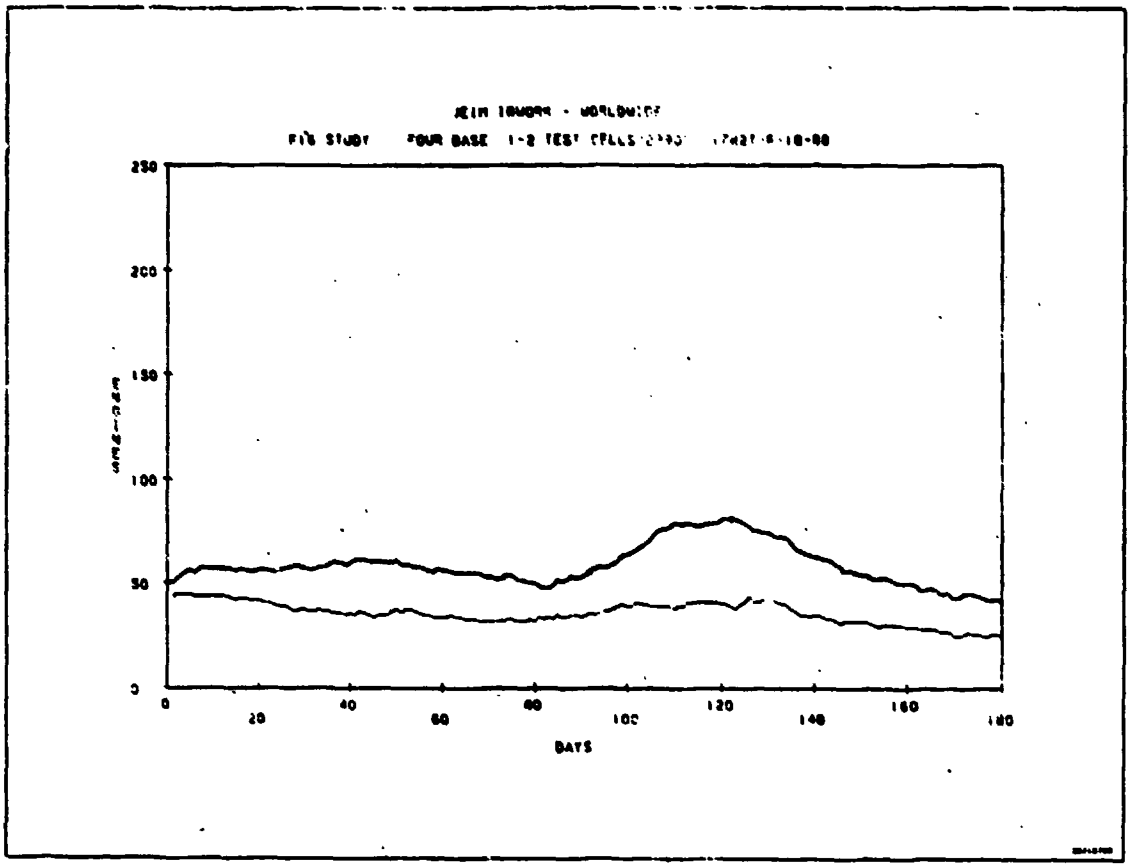
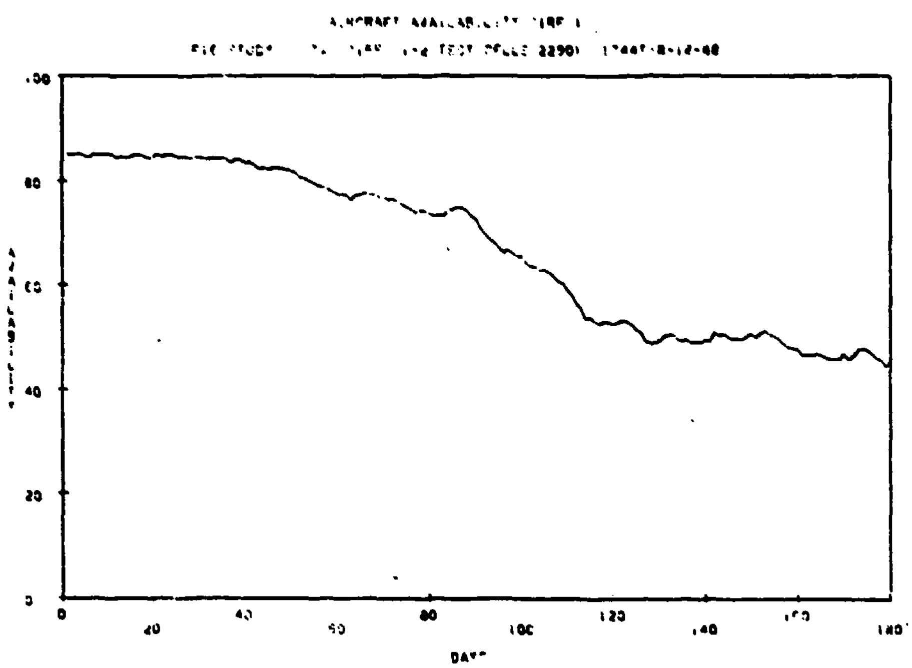


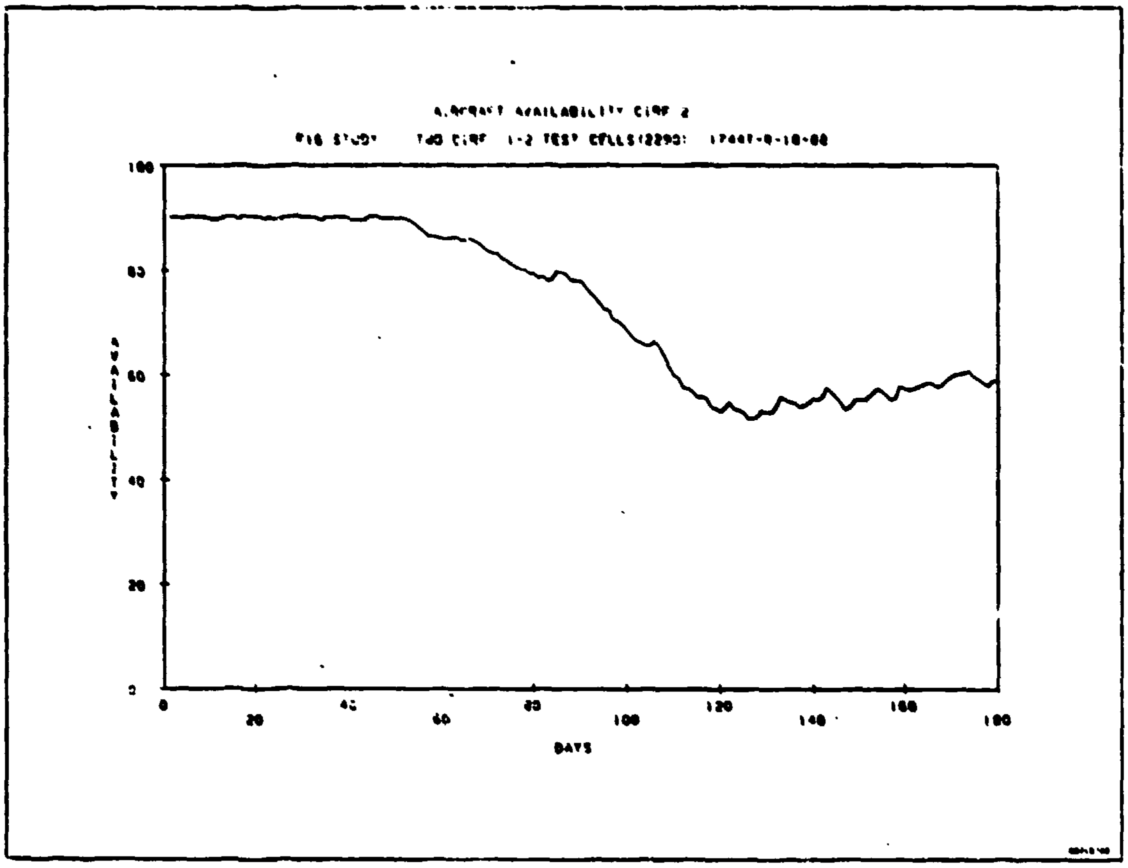
WORLDWIDE INNWORK (ORGANIC JEIM)



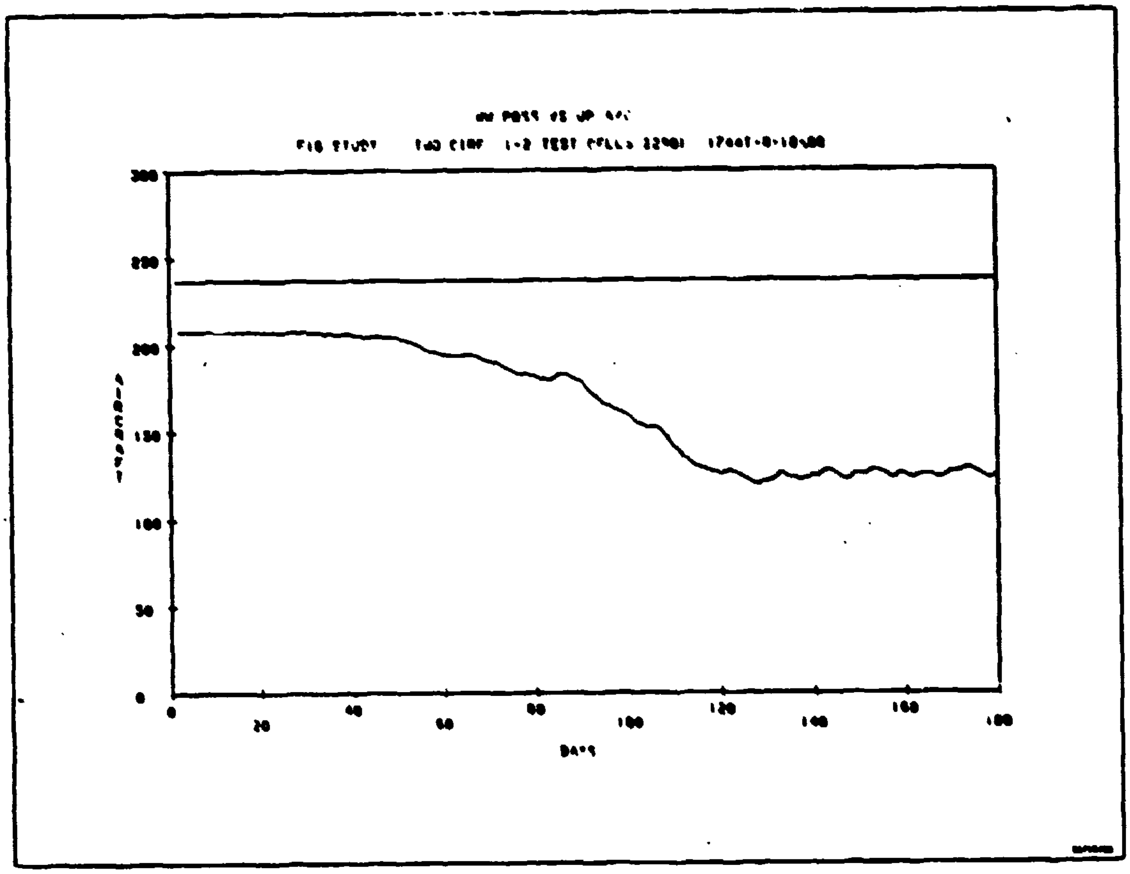
PACAF CENTRALIZED JEIM (INCREASED REPAIR CYCLE)



USAFE CENTRALIZED JEIM (INCREASED REPAIR CYCLE)



WORLDWIDE AVAILABILITY (INCREASED REPAIR CYCLE)



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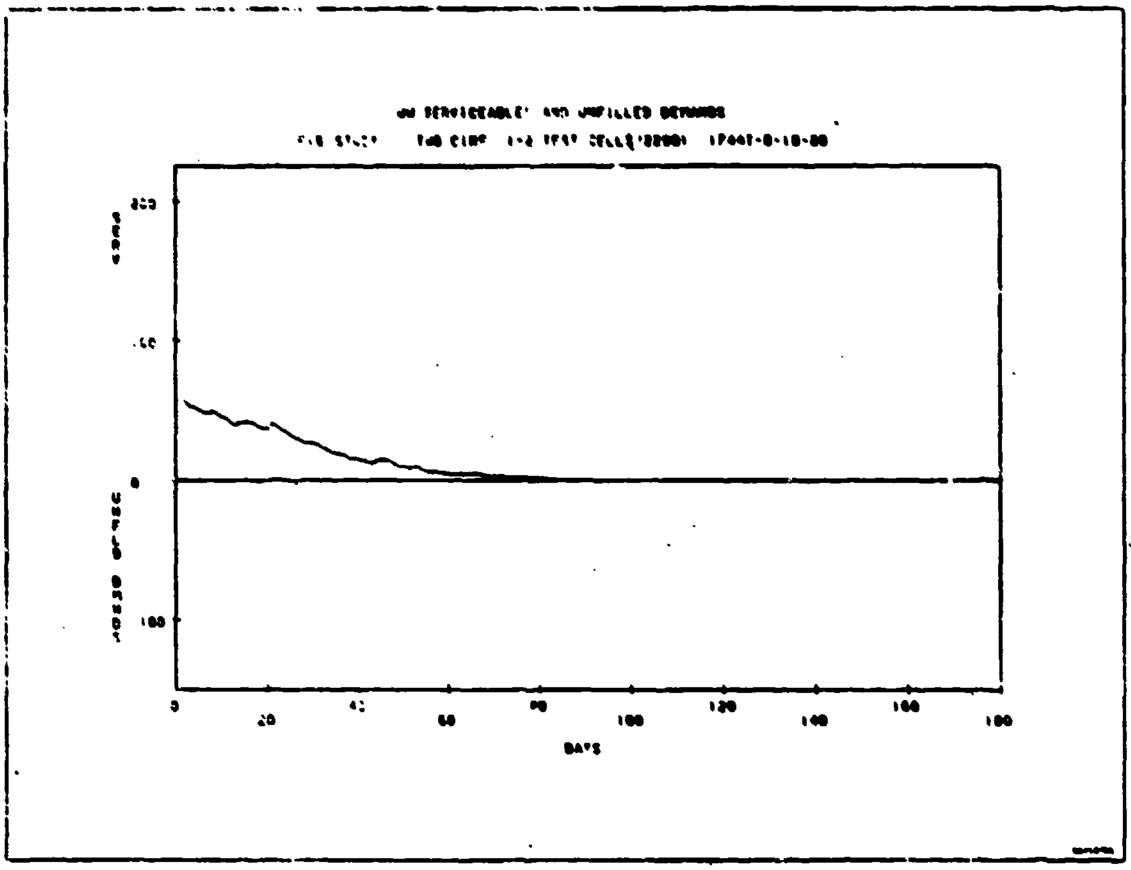

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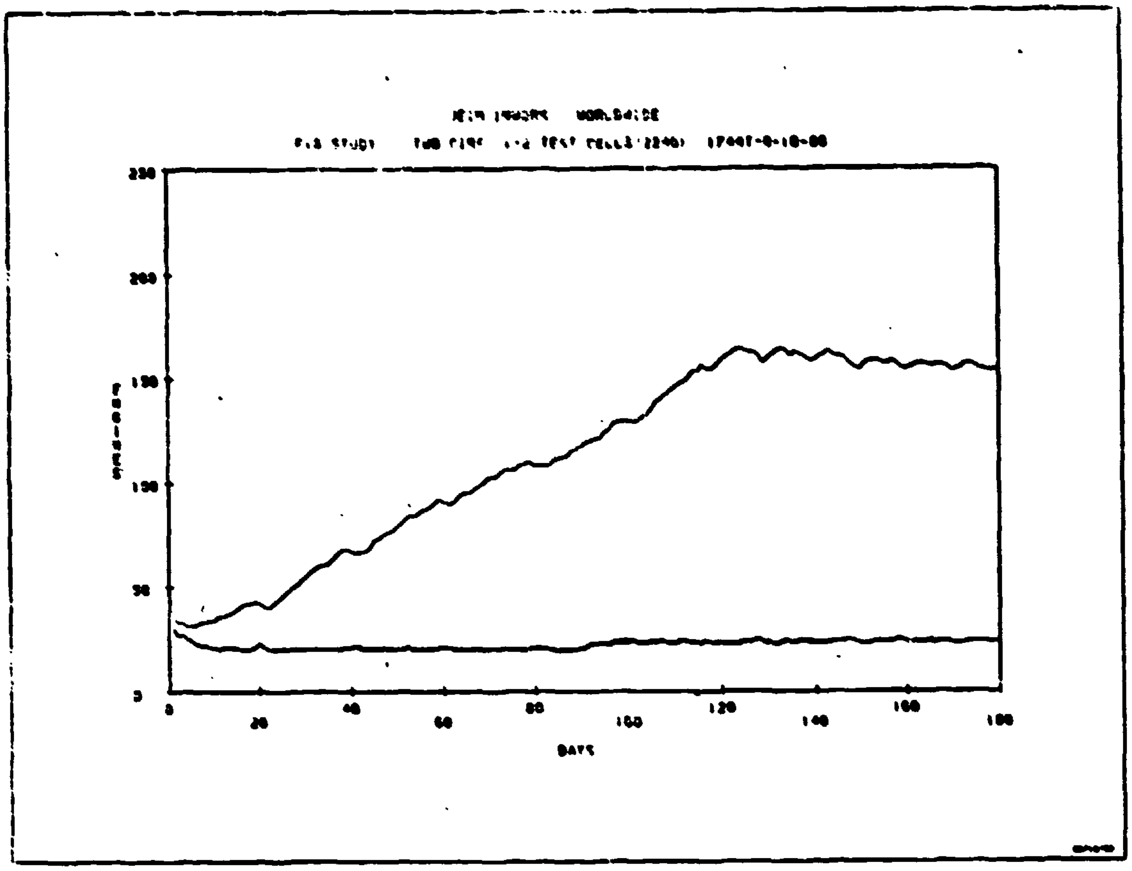
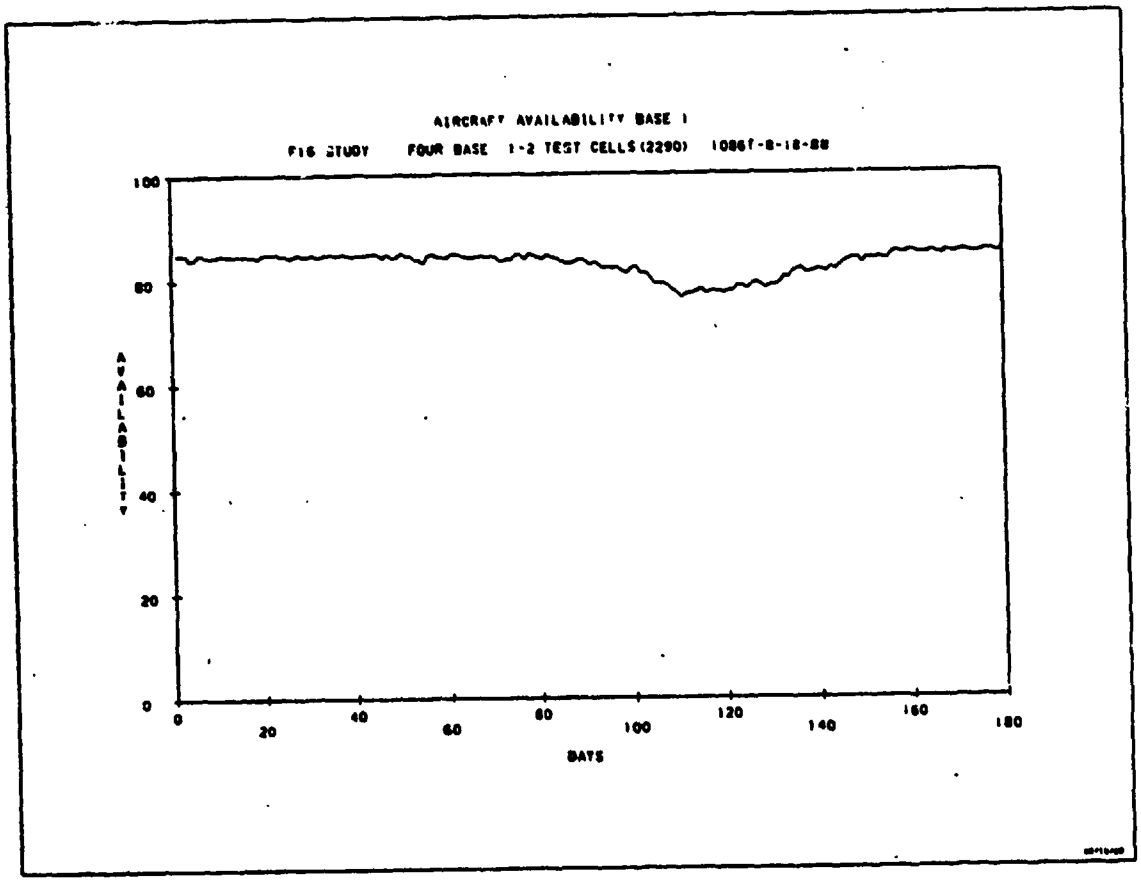
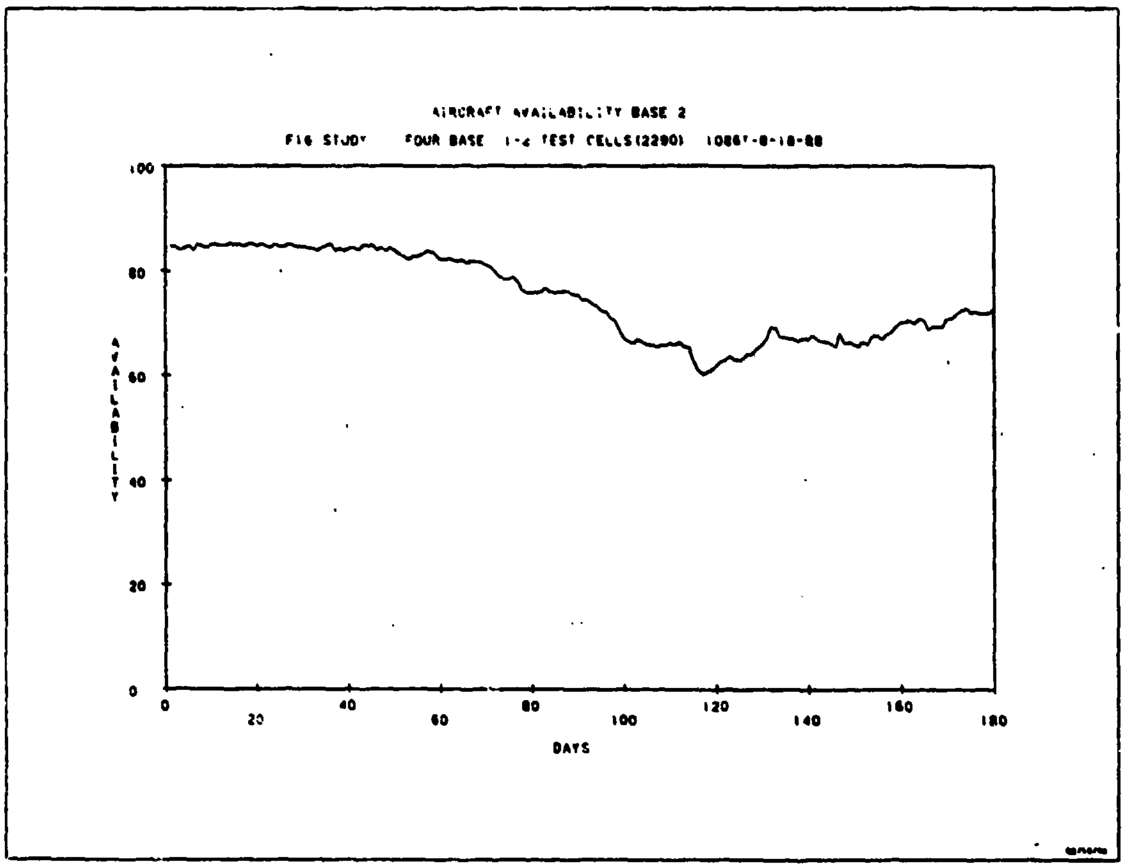


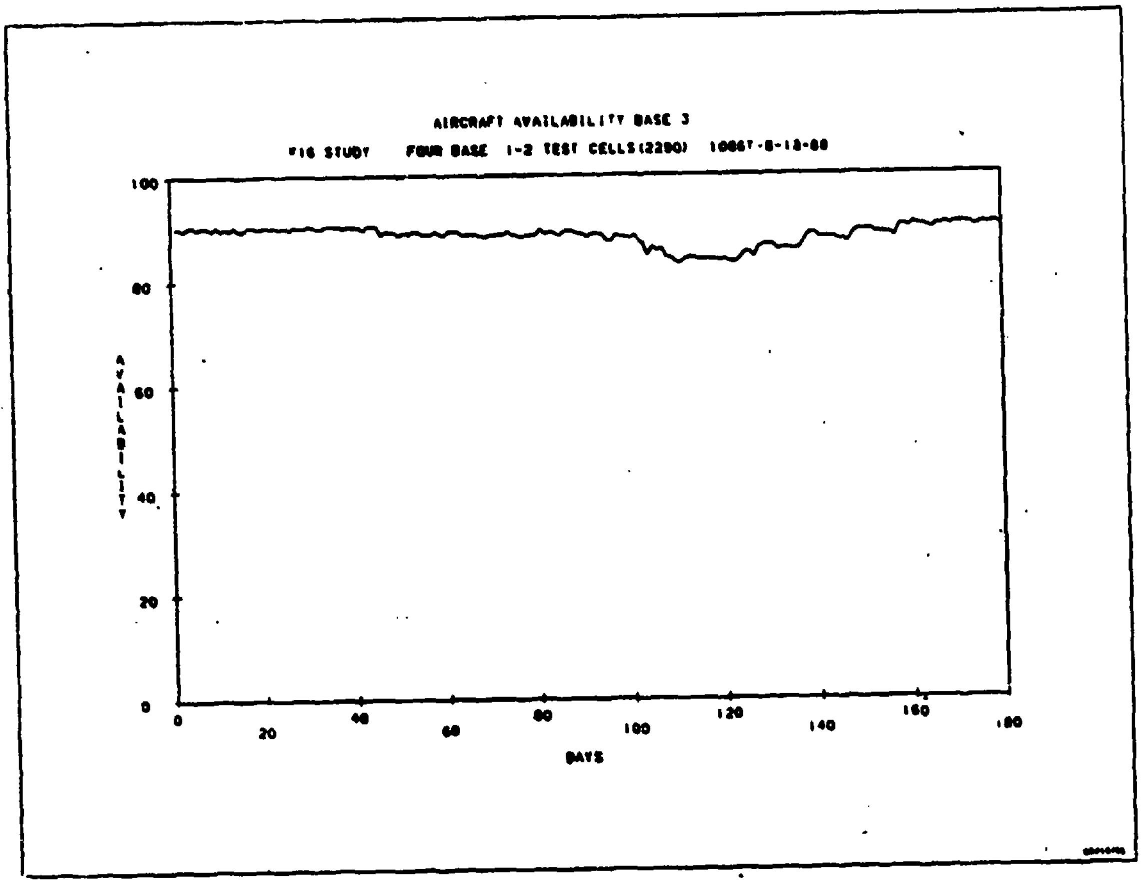
MISAWA AVAILABILITY (INCREASED REPAIR CYCLE)



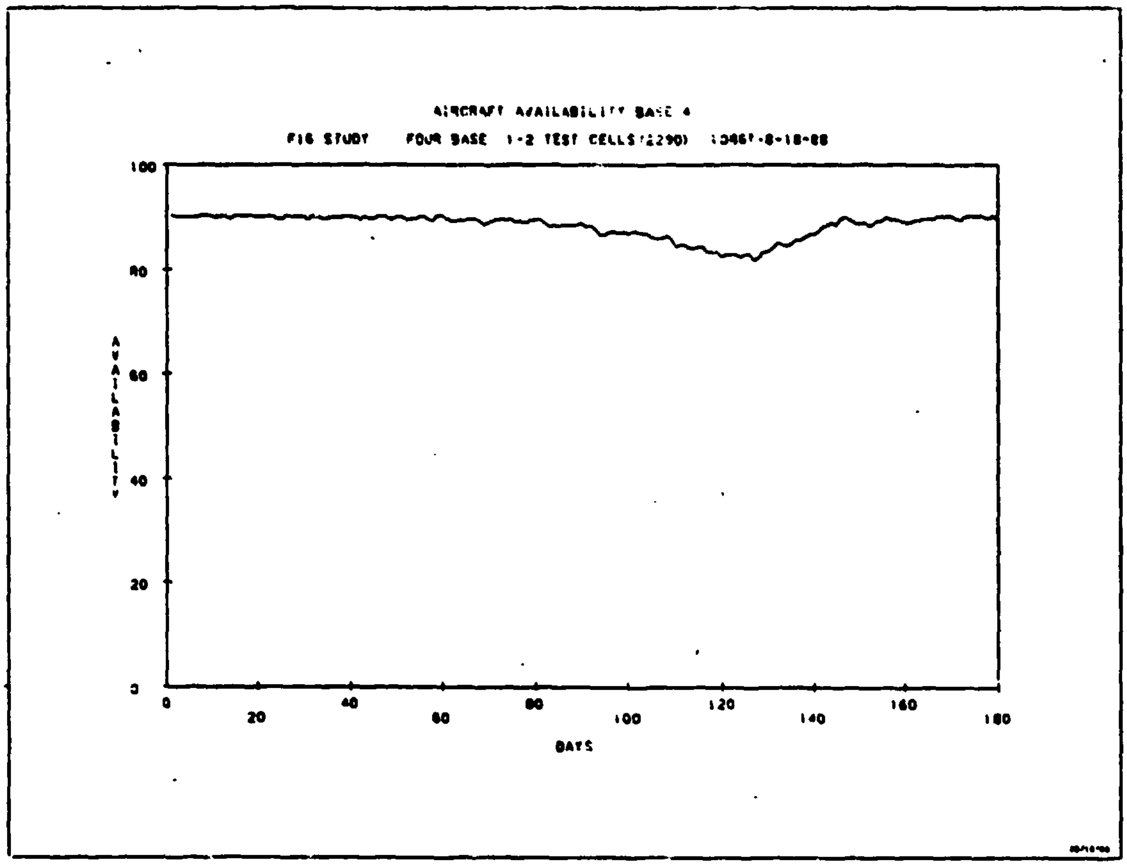
KUNSAN AVAILABILITY (INCREASED REPAIR CYCLE)



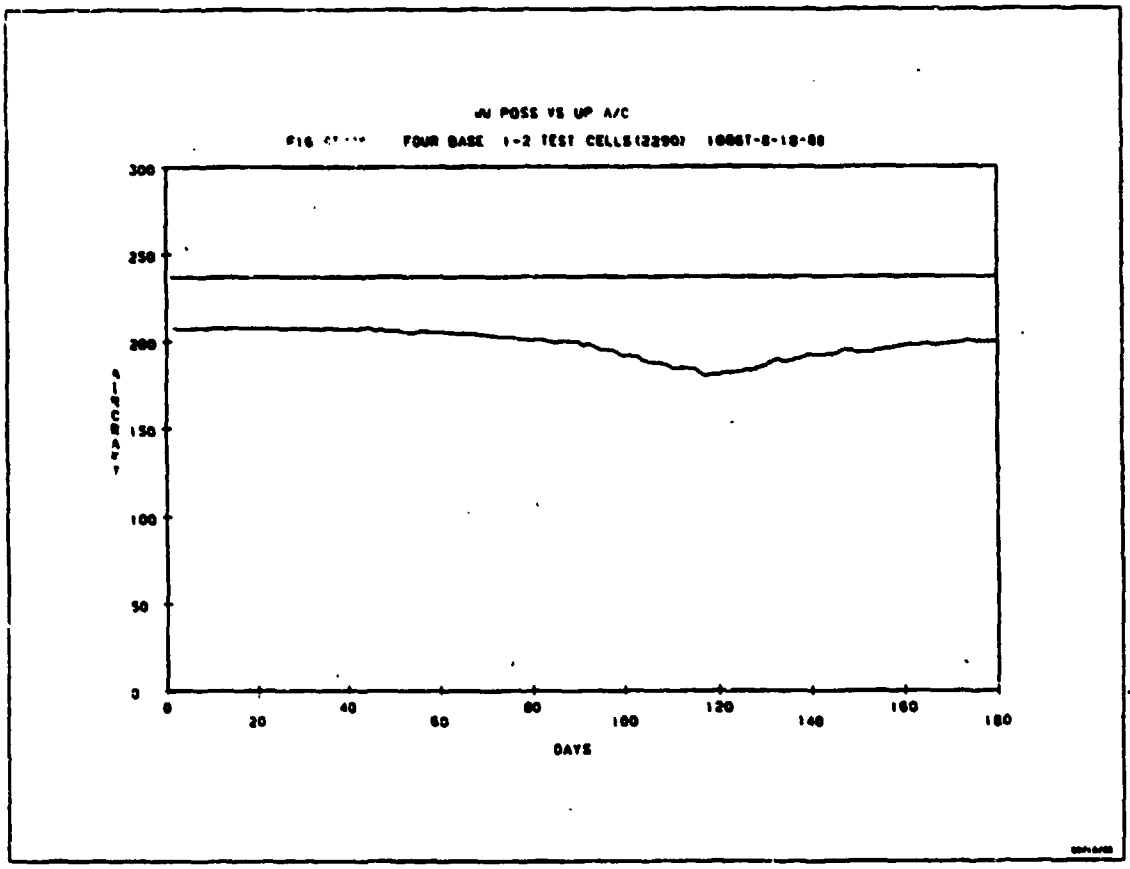
RAMSTEIN AVAILABILITY (INCREASED REPAIR CYCLE)



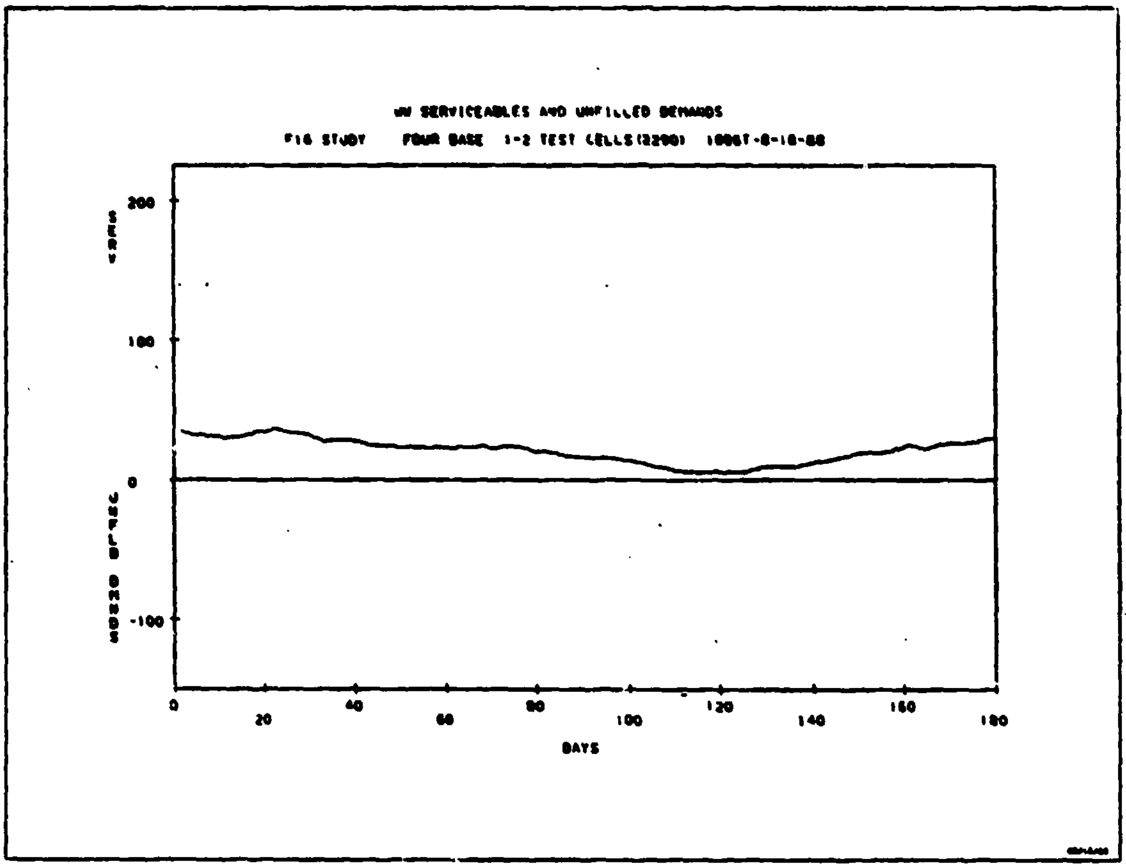
TORREJON AVAILABILITY (INCREASED REPAIR CYCLE)



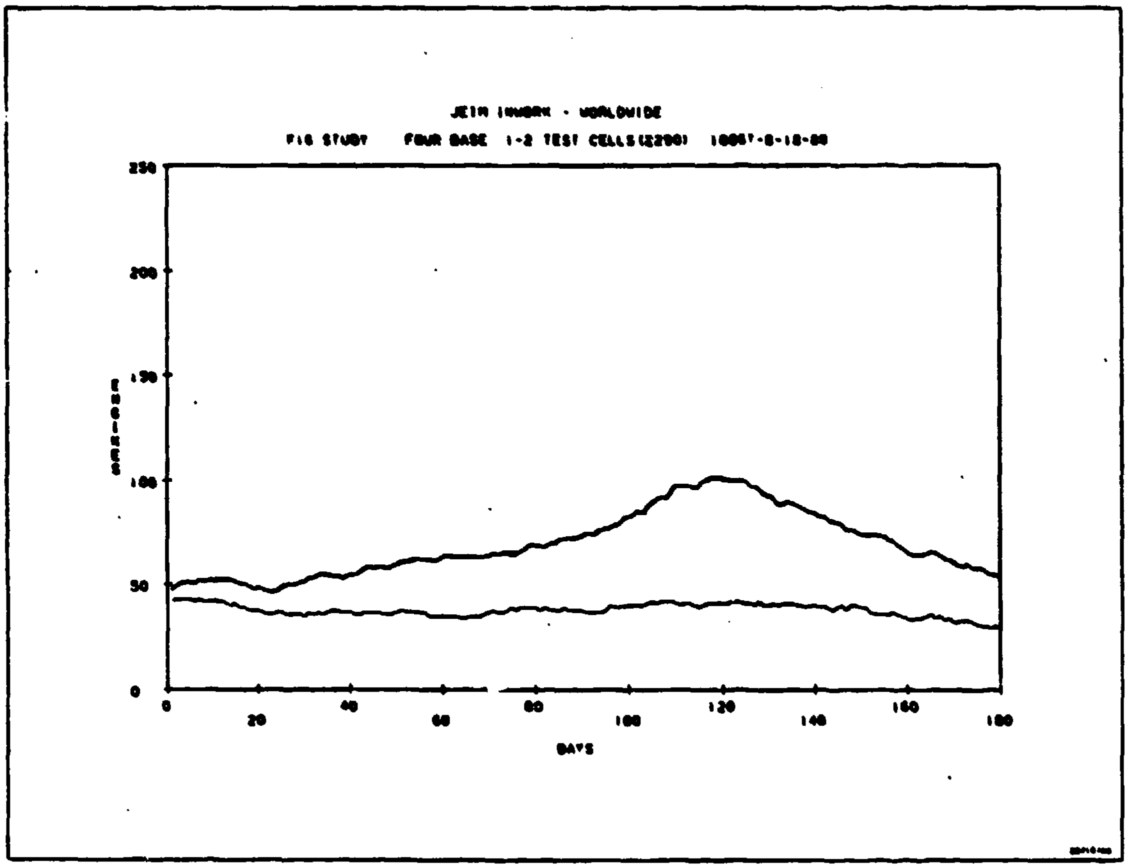
WORLDWIDE AVAILABILITY (INCREASED REPAIR CYCLE)



WORLDWIDE SERVICEABLES (INCREASED REPAIR CYCLE)



WORLDWIDE INWORK (INCREASED REPAIR CYCLE)



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The purpose of this study was to evaluate the relative performance and cost of centralized intermediate maintenance versus traditional organic maintenance. The study had three objectives: 1) Measure peacetime readiness performance for centralized and organic intermediate maintenance, 2) Measure wartime combat capability performance for both maintenance concepts, 3) To compare maintenance costs between centralized and organic intermediate maintenance concepts.

The objectives were accomplished through statistical analysis of the Jet Engine Maintenance Simulator (JEMS) simulation model for F16 F110 engines. The cost comparisons were obtained from Air Force Logistics Command (AFLC) agencies and the F16 Systems Program Office (SPO).

Analysis of the simulation results found that peacetime readiness rates were statistically the same for 26 of 30 peacetime simulations. Of the four results which showed significant differences, three favored organic maintenance while one favored centralized maintenance. Different simulations were made for varying transit times, maintenance crews, and quantity of spares.

The wartime results found statistical differences in aircraft availability on 20 of the 30 simulation runs. Of these, 16 found higher availability rates for organic maintenance while four found higher rates for centralized structures.

The sustained results found statistical differences in aircraft availability on 28 of the 30 runs. Of these, 25 found higher availability rates for organic maintenance while three found higher rates for centralized structures.

The estimated cost differential for the maintenance structures over the 180 day scenario was $7,458,276. This cost difference included estimates for intermediate support, transportation, initial spares, war reserve spares kits (WRSK), spare F110 engines, replenishment spares, and support equipment.

This study recommended that organic engine support be maintained for F110 engines and that organic intermediate maintenance be preferred for maximum combat capability.